LOOP 14-YR MONITORING PROGRAM

SYNTHESIS REPORT

Prepared for

LOOP, INC.
1 SEINE COURT, SUITE 500
NEW ORLEANS, LA 70174-6638

Prepared by

BARRY A. VITTOR & ASSOCIATES, INC.
8060 COTTAGE HILL ROAD
MOBILE, ALABAMA 36695

May 1995

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

PROJECT BACKGROUND AND HISTORY

This report summarizes results of fourteen years of monitoring hydrography, sediments, and macroinfaunal assemblages in association with activities of the Louisiana Offshore Oil Port, Inc. (LOOP). The LOOP monitoring program was designed to assess effects of pipeline construction, brine discharge, and operation of an offshore port and pumping station complex on sediment characteristics and macroinfaunal assemblages. The LOOP facility was designed to pump oil from a deepwater mooring system to an inland storage cavern. The cavern was excavated by injecting freshwater from nearby water sources into the Clovelly salt dome. The resulting concentrated brine solution has been discharged offshore through a diffuser system. The monitoring program originally included three study areas: 1) inland pipeline and Clovelly salt dome sites; 2) brine diffuser; and 3) the offshore pumping station and single-point mooring facility. For the purposes of this report the inland areas were divided on the basis of salinity into two ecologically distinct habitats, the Clovelly salt dome sites and the pipeline monitoring stations at Lake Jesse. The macroinfaunal monitoring program was under the supervision of the Louisiana Department of Wildlife and Fisheries (LDWF) for LOOP. The first full year of monitoring began in 1980 and has continued until the present.

OBJECTIVE OF SYNTHESIS

The objectives of this report were to provide a general summary of hydrographic and macroinfaunal data collected from 1980 to 1993. The data were analyzed with regards to seasonal, year-to-year, and between station variation in hydrography and macroinfaunal assemblages for each of the four habitats. The data permitted an evaluation of any potential impacts of LOOP activities by evaluating long-term variation in selected hydrographic and macroinfaunal variables at monitoring and control stations.

METHODS

The study design, methodologies, and data analyses used in the benthic portion of the monitoring program were given in a November, 1980 annual report submitted to LOOP and LDWF by Barry A. Vittor & Associates, Inc. (BVA). The monitoring program was modified in 1982 and included a reduction in the overall number of stations sampled and the replacement of several stations. These changes were discussed in a January, 1984 annual report submitted to LOOP and LDWF by BVA. A 5-year summary (1980-1984) report of the monitoring program was submitted to LDWF in March, 1987 by BVA.

Benthic samples were collected quarterly (winter, spring, summer, and fall seasons) by personnel of LDWF and processed in BVA's laboratories. Hydrographic and sediment data were also collected quarterly by LDWF and provided to BVA on an annual basis.

The raw data for this 14-year synthesis report were assembled and transferred to a digital spreadsheet format by BVA personnel. Selected data were graphically and statistically analyzed by both season and year. To assess differences between control and monitoring stations at the four sites, data for each season were combined over the 14 years. The seasonal summary data for total number of taxa and total density were first tested for normality (Shapiro-Wilk W; SAS Institute, 1994), and if normally distributed for homogeneity of variances (Bartlett's test; SAS Institute, 1994). Due to a consistent lack of normally distributed data with common data transformations, differences between all control/monitoring stations in total taxa and total densities for a given season were analyzed using non-parametric techniques (Wilcoxon/Kruskal-Wallis comparisons; SAS Institute, 1994). Correlations between variables on a yearly basis were calculated using non-parametric measures of association (Spearman Rho; SAS Institute, 1994).

LOCATION OF MONITORING SITES

Two inland locations were selected to monitor impacts due to pipeline construction and operations associated with the Clovelly salt dome oil storage facility (salt dome excavation and oil transfer). Stations 461, 463, and 464 are located at the Clovelly salt dome and are the most inland sites with water depths of 2-3 m (Fig. 1, Table 1). Station 461 is a control station in Little Lake, while stations 463 and 464 are associated with the Clovelly facility and freshwater intake canal (Table 1). Stations 407 and 462 are located along the pipeline at Lake Jesse in water depths of 1 m (Fig. 1, Table 1). Station 407 is a control station located in Lake Jesse and station 462 is a monitoring station for the pipeline.

The brine diffuser is located approximately 6.4 km offshore at 10-11 m depth. Four stations were associated with the brine diffuser. Originally, monitoring stations were established to provide for adequate coverage in the direction of the prevailing westerly currents, and in areas predicted to experience elevated salinities based on brine dispersion models for the areas. Stations 473, 474, and 475 are located on a concentric ring 150 m from the diffuser (Fig. 2, Table 2). Station 435 is a control station located 3.2 km NE of the brine diffuser.

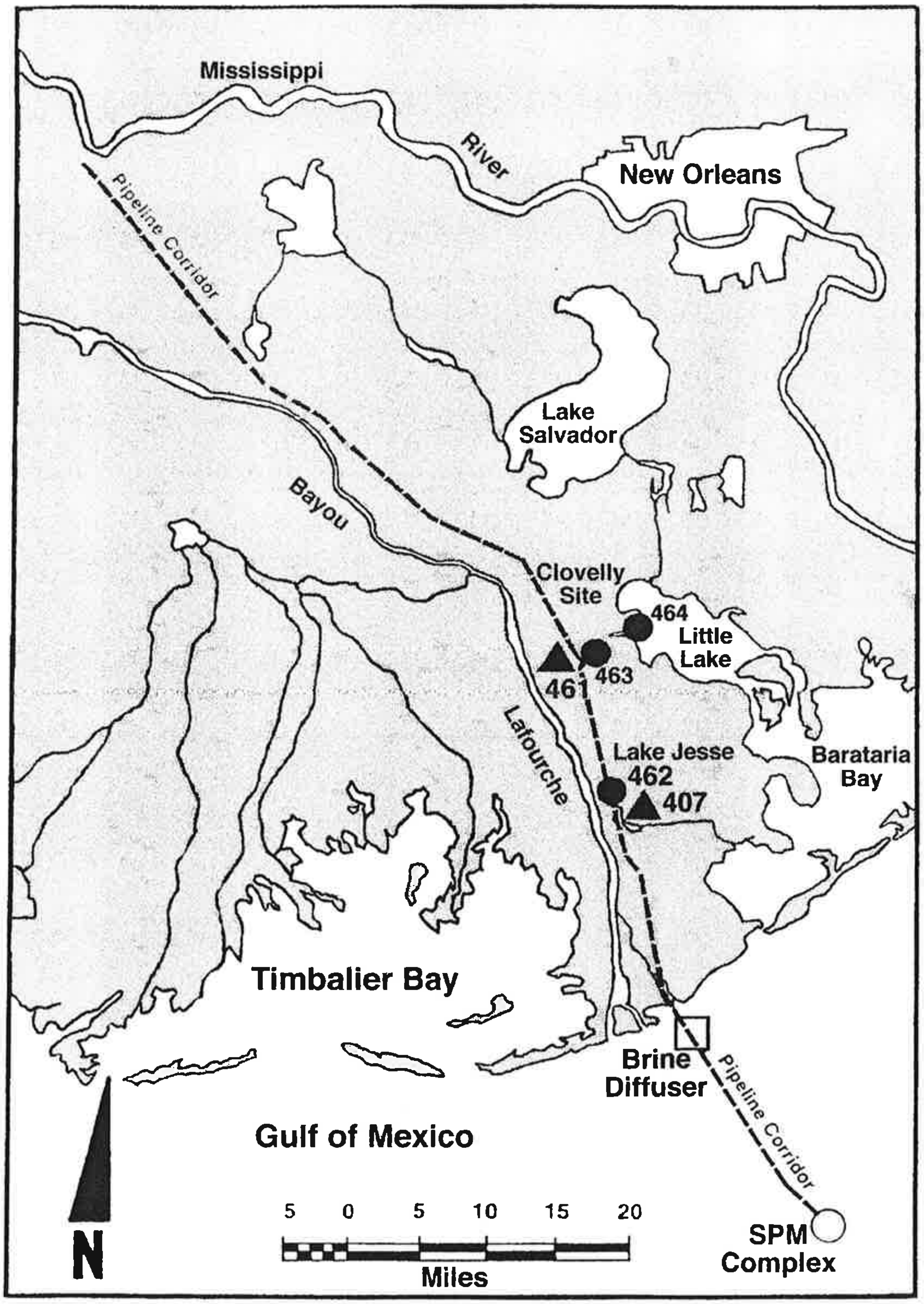


Figure 1. A map of the LOOP monitoring area indicating locations for the inland Clovelly/freshwater intake stations and the inland pipeline stations at Lake Jesse. The relative locations of the brine diffuser, SPM complex, and pipeline corridor are also indicated on the map.

Table 1. Coordinates and site descriptions for the LOOP inland Clovelly/freshwater intake stations and inland pipeline monitoring stations at Lake Jesse.

INLAND STUDY AREAS

Station Number	Coordinates Latitude	Longitude	Location Description
407	29°15'18"	90°11'22"	462 control, Lake Jesse (MS #7) just east of center of lake at 1 m depth
462	29°15'17"	90°11'46"	Lake Jesse (CS #43) west of center, off spoil bank at 1 m depth
461	29°27'41"	90°15'53"	463 control, entrance to first dead end canal west in dead end canal complex, 915 m WNW of 463 at 1.2 m depth
463	29°28'32"	90°15'19"	Clovelly 46 m N of freshwater intake at canal entrance at 1.7 m depth
464	29°30'07"	90°13'03"	Superior Canal E side of entrance to Little Lake (MS #15), 27 m SW of MS #15 at 2.7 m depth

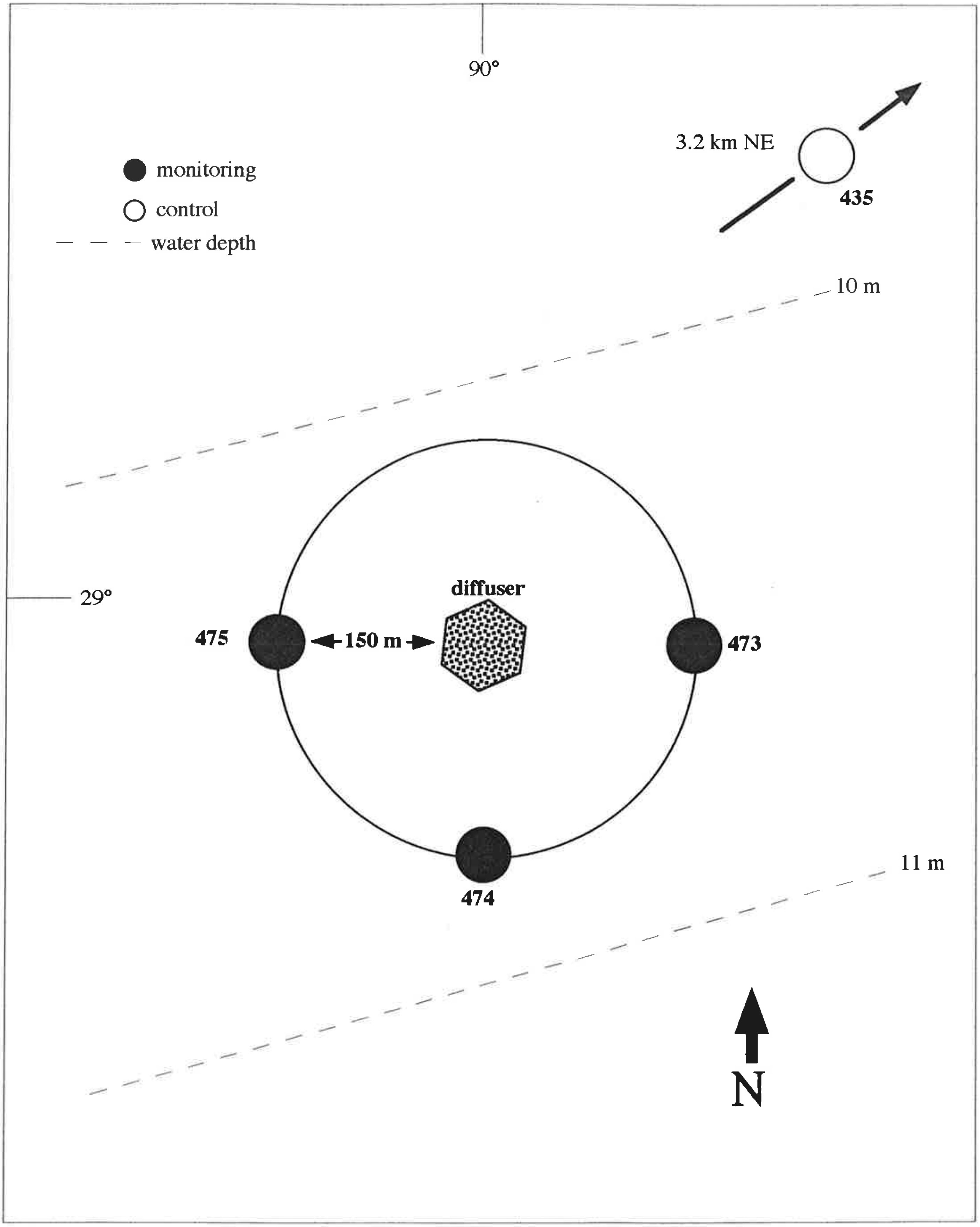


Figure 2. A schematic map of the LOOP brine diffuser control and monitoring stations.

Table 2. Coordinates and site descriptions for the LOOP brine diffuser control and monitoring stations.

BRINE DISPOSAL AREA

Station Number	Coordinates Latitude	Coordinates Longitude	Loran W	Loran X	Location Description
435	29°07'22"	90°05'00"	11722.1	28438.1	Control, MS #35 46 m W of Hunt Platform 104-4-G124-5 at 10 m depth
473	29°06'01'	90°06'50"	11713.75	28413.56	150 m E of diffuser at 10 m depth
474	29°05'51"	90°06'50"	11713.56	28412.51	150 m S of diffuser at 10 m depth
475	29°06'01"	90°07'06"	11712.61	28411.89	150 m W of diffuser at 9.5 m depth

The offshore site includes the pipeline corridor, pumping station complex, and single-point mooring facility (SPM; Fig. 3). Station 481 is located at the pumping station and SPM complex approximately 27.8 km offshore at depths of 33-35 m (Fig. 3, Table 3). Control stations 482 and 484 are located 4.8 km NE and 1.6 km SW of the pumping station complex, respectively (Fig. 3, Table 3).

RESULTS I. CLOVELLY FRESHWATER INTAKE AND LITTLE LAKE

SEASONAL SUMMARY OF HYDROGRAPHY

A seasonal summary of hydrographic characteristics for the Clovelly/freshwater intake stations is given in Fig. 4. There was considerable spatial and temporal variation in the percentage of sand in the sediment at the three stations. The greatest variation was observed during the fall months when the percent sand varied from 11% at control station 461 to 44% at Little Lake station 464 (Fig. 4). Control station 461 consistently had a finer sediment texture than the two monitoring stations. Interstitial salinity averaged 4 ppt for the three stations and was highest during the fall sampling period (Fig. 4). Interstitial salinity exhibited little variation between stations. Bottom dissolved oxygen exhibited temporal variability and was highest during the winter and fall sampling periods and lowest during the spring and summer (Fig. 4). There was little variation between stations in bottom dissolved oxygen.

SEASONAL SUMMARY OF MACROINFAUNAL ASSEMBLAGE

A seasonal summary of general characteristics of the macroinfauna assemblage for the Clovelly/freshwater intake stations is given in Fig. 5. There were no significant differences between average number of taxa collected and mean total density at the three stations for a given season (Table 4). The average number of taxa collected was 30.3, 28.6, 30.0, and 31.7 for the winter, spring, summer, and fall seasons, respectively. Mean total densities were highest in the winter (average = 5176.2 individuals/m^2) and lowest during the spring (average = 3014.8 individuals/m^2). Densities at station 464 averaged 7794.4 individuals/m^2 during the summer months; however, due to high year-to-year variation in densities, this value was not significantly different than summer densities at stations 461 and 463 (Fig. 5). There was little variation between station and season in taxa diversity (H') and H' averaged 2.1 across all stations and seasons (Fig. 5).

YEARLY SUMMARY OF HYDROGRAPHY

Yearly variation in hydrography for the Clovelly/freshwater intake stations is summarized in Fig. 6. There was considerable spatial and temporal variation in the percentage of sand in the sediments at the three stations and

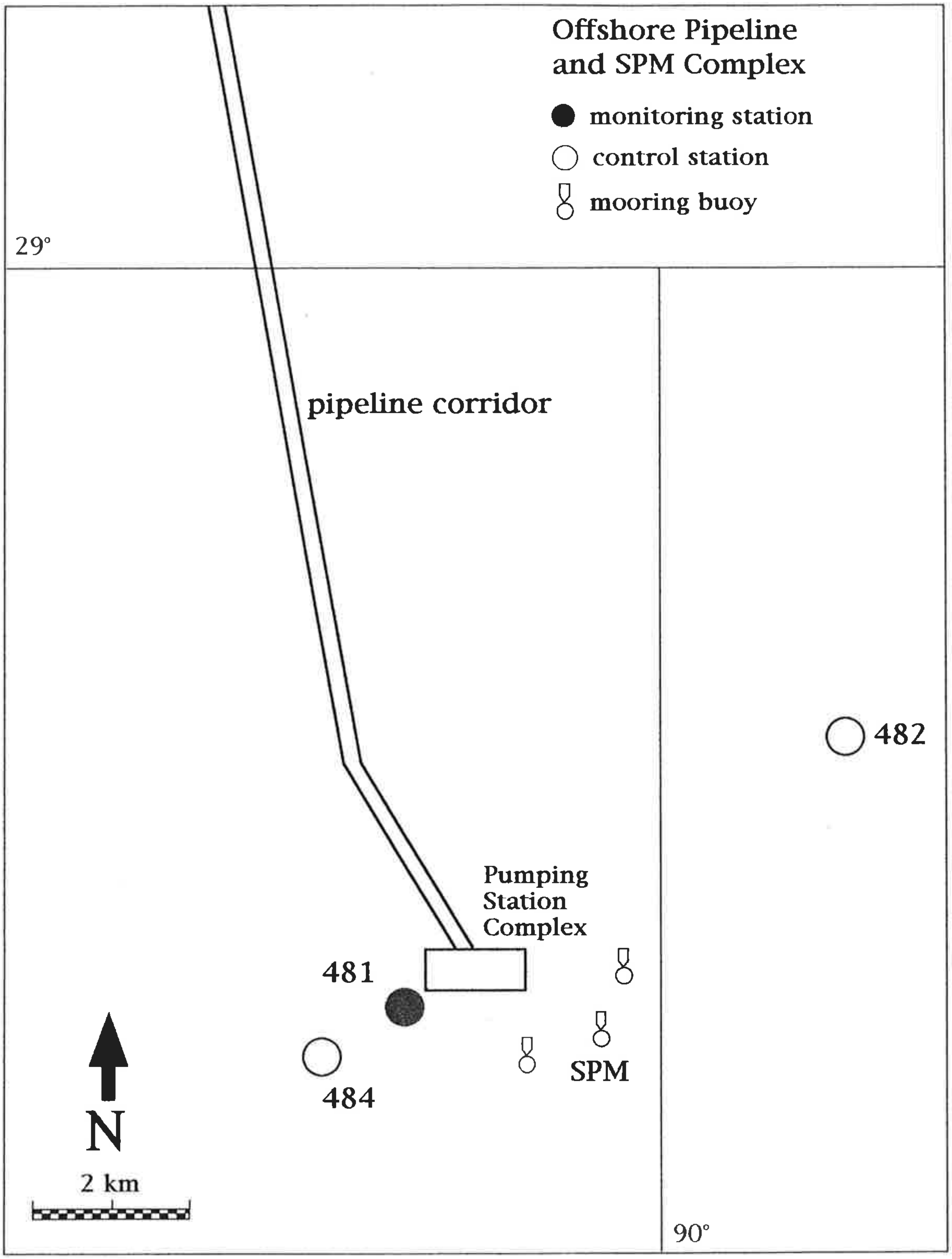


Figure 3. A schematic map of the LOOP offshore pumping station complex and SPM facility control and monitoring stations.

Table 3. Coordinates and site descriptions for the LOOP offshore pumping station complex and SPM facility control and monitoring stations.

OFFSHORE PIPELINE COMPLEX & SPM

Station Number	Coordinates Latitude	Longitude	Loran W	Loran X	Location Description
481	28°56'06"	90°01'30"	11789.72	28408.35	91 m W of pumping station platform at SPM complex approximately 27.8 km offshore at 34 m depth
482	28°54'48"	89°59'05"	11801.19	28440.43	481 Control, 4.8 km NE of pumping station platform at 34 m depth
484	28°56'12"	90°04'07"	11763.12	28396.69	1.6 km SW of platform near QS #51 at 27 m depth

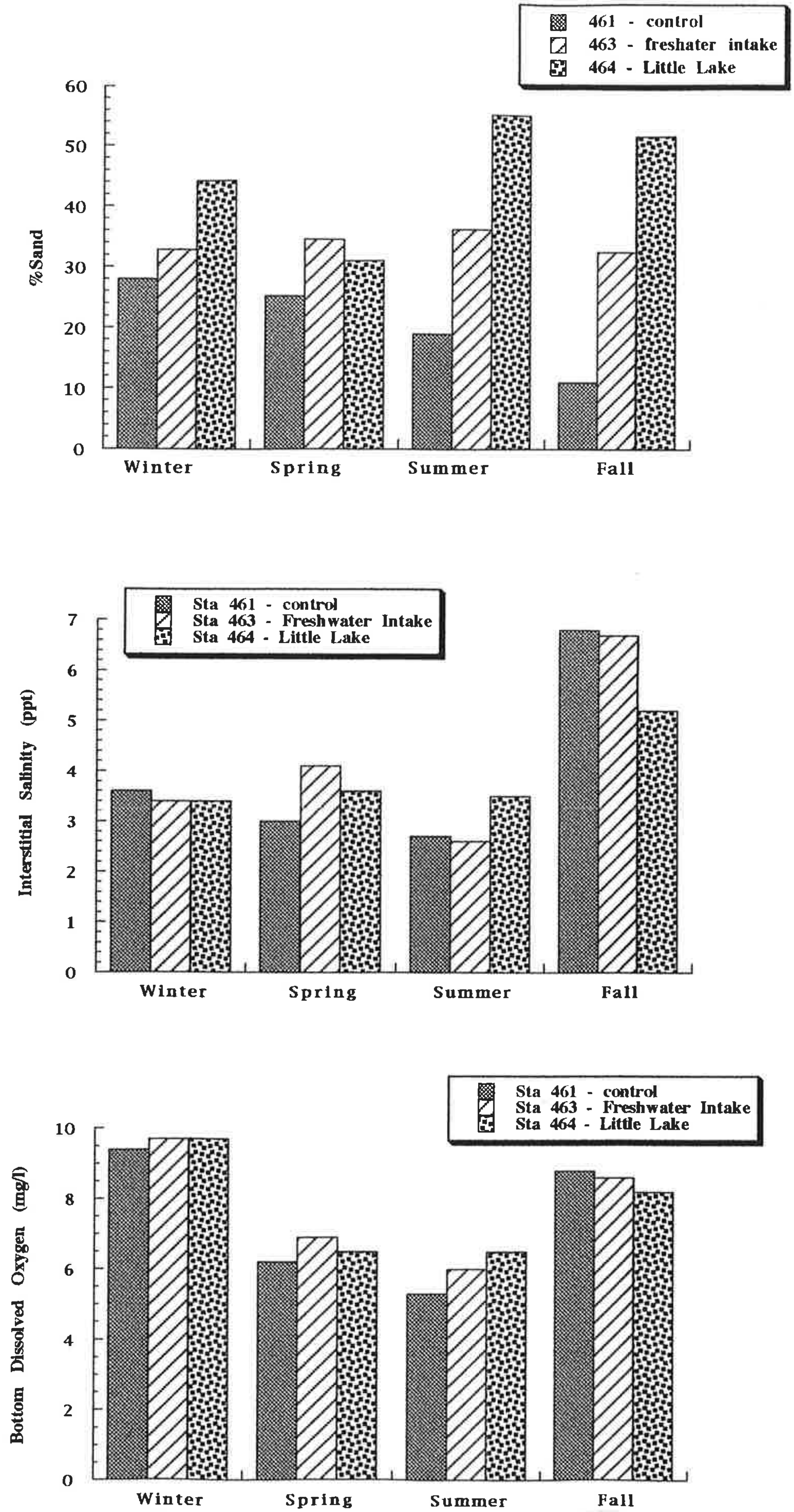


Figure 4. Seasonal summaries of hydrographic parameters over the 14-year LOOP monitoring program for the inland Clovelly/freshwater intake control and monitoring stations.

Table 4. Results of various statistical analyses for the LOOP inland Clovelly/freshwater intake stations. The results of non-parametric Kruskal-Wallis comparisons of total number of taxa or mean density between stations for a given season are presented in Part A. The results of non-parametric analyses for correlations between stations in major taxonomic groups is given in Part B. The results of non-parametetric analyses for correlations between stations in major taxa/species is given in Part C.

(A)

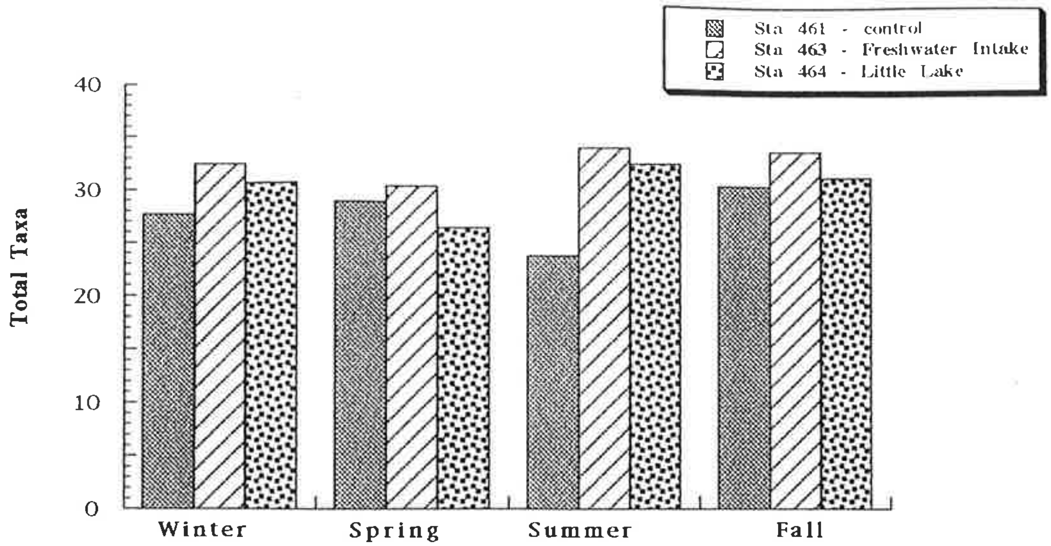
Season	Mean Total Taxa: Chi Square	Mean Total Taxa: Prob > Chi Sq	Mean Density: Chi Square	Mean Density: Prob > Chi Sq
Winter	1.252	0.525	0.447	0.800
Spring	0.492	0.782	0.573	0.751
Summer	4.621	0.099	4.116	0.128
Fall	0.843	0.656	0.367	0.832

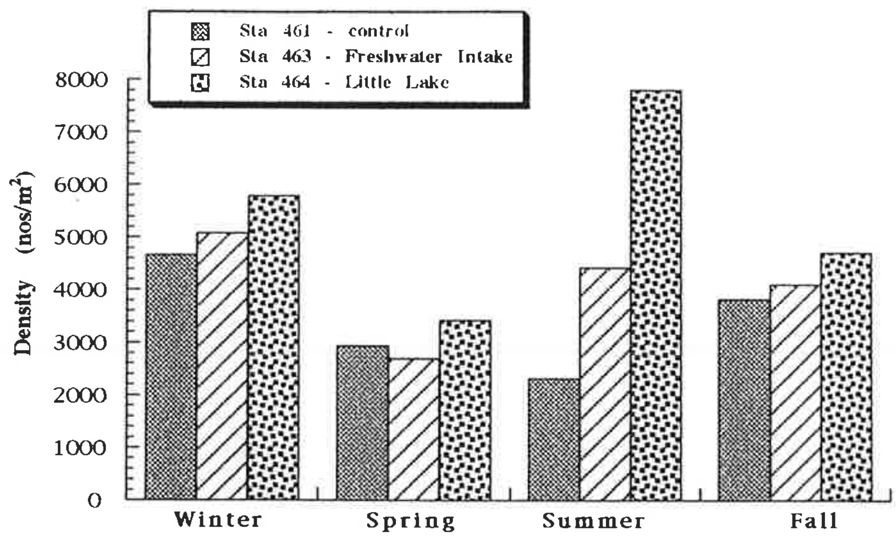
(B)

Station	Variable	by	Station	Variable	Spearman Rho	Prob > Rho
461	Mollusca		461	Annelida	-0.4392	0.0007
461	Arthropoda		461	Annelida	-0.9638	0.0000
461	Arthropoda		461	Mollusca	0.2338	0.0829
463	Mollusca		463	Annelida	-0.5625	0.0000
463	Arthropoda		463	Annelida	-0.8514	0.0000
463	Arthropoda		463	Mollusca	0.1907	0.1591
464	Mollusca		464	Annelida	-0.0519	0.7043
464	Arthropoda		464	Annelida	-0.5580	0.0000
464	Arthropoda		464	Mollusca	-0.6449	0.0000

(C)

Station	Variable	by	Station	Variable	Spearman Rho	Prob > Rho
463	*Hobsonia*		461	*Hobsonia*	0.3509	0.0080
461	*Grandidierella*		463	*Grandidierella*	0.5926	0.0000
463	*Chironomidae*		461	*Chironomidae*	0.4899	0.0001





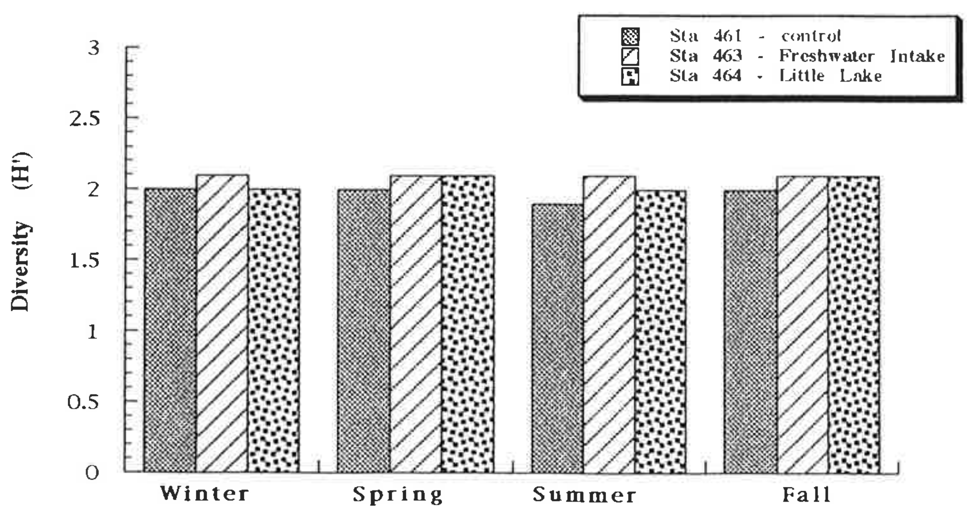


Figure 5. Seasonal summaries of characteristics of the macroinfaunal assemblage over the 14-year LOOP monitoring program for the inland Clovelly/freshwater intake control and monitoring stations.

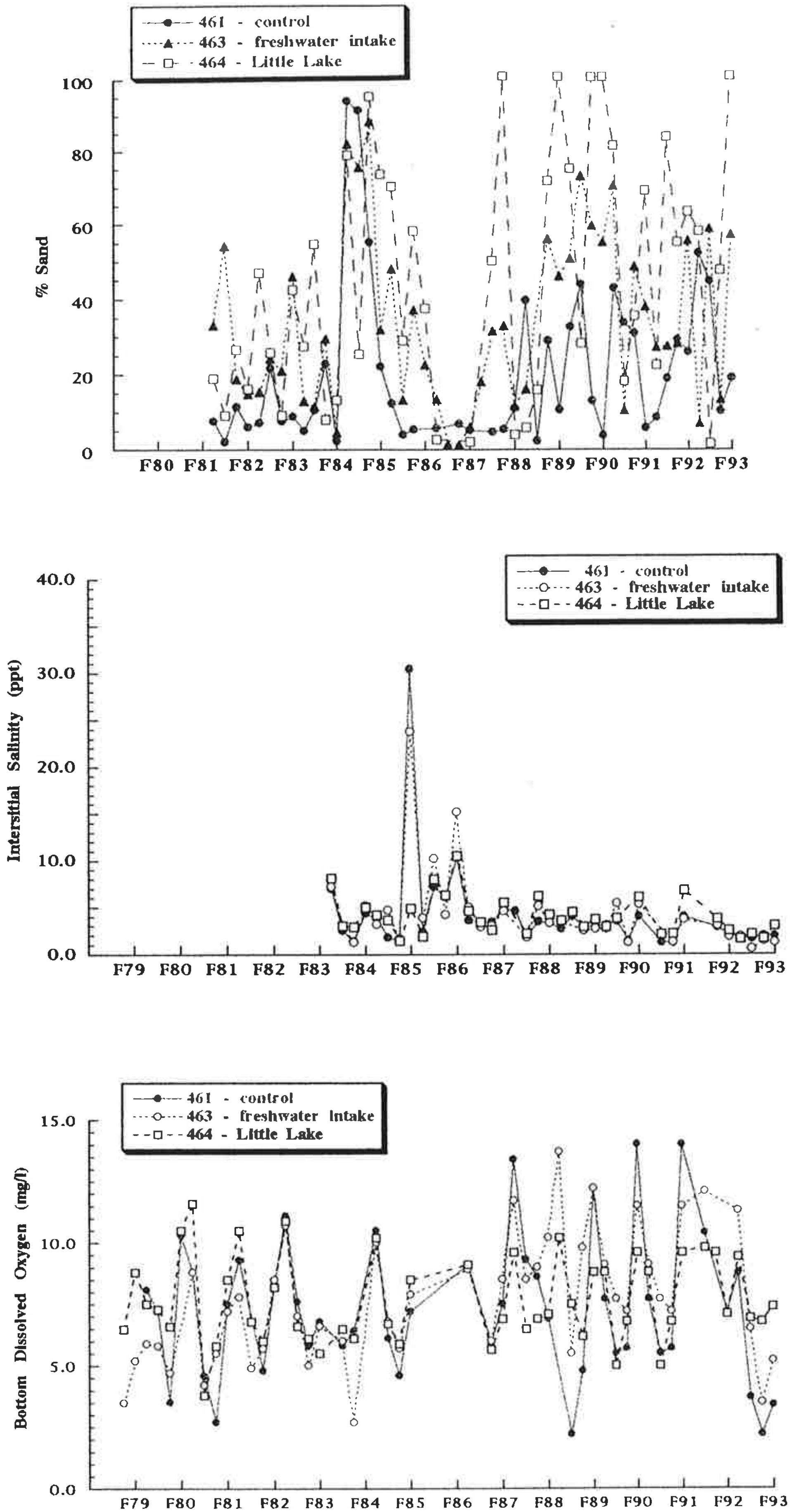


Figure 6. Yearly summaries of hydrographic parameters over the 14-year monitoring program for the inland Clovelly/freshwater intake control and monitoring stations.

ranged from near zero to 100%. Major peaks in percent sand appeared to correspond with seasonal periods of high discharge. High discharge often results in a flushing of fine particulates from the sediments. There was a pronounced decrease in the amount of sand in the sediments during 1986-88 for control station 461 and during 1987 for stations 463 and 464 (Fig. 6). These observations may be related to both the effects of hurricane Juan which made landfall in the vicinity of the Clovelly stations during October 1985, and an above average rainfall year in 1986 (Fig. 7). It is probable that elevated discharge levels associated with these events resulted in the deposition of fine sediments in Little Lake and associated canals. There was also a statistical trend towards an increase in the percentage of sand in the sediments at station 464 (Fig. 8).

Interstitial salinities exhibited similar seasonal patterns between stations and were generally less than 5 ppt indicating brackish water (Fig. 6). These inland stations had the lowest interstitial salinities of all sites in the LOOP monitoring program. Stations 461 and 463 had dramatically elevated salinities during the fall 1995 sampling (> 23 ppt). Elevated salinities were measured at all stations during the winter 1984 sampling period and during the spring and fall 1986 samplings.

Bottom dissolved oxygen (DO) levels showed extreme temporal variation ranging from > 2 to 14 mg/l (Fig. 6). Stations 461, 463 and 464 had similar temporal patterns in DO levels. Lowest DO levels (< 5 mg/l) occurred during the summer months, while highest levels were observed in the winter (Fig. 6). Summer and early fall months in northern Gulf of Mexico estuarine habitats generally exhibit low bottom DO levels (Gaston 1985, Gaston and Edds 1994, Rabalais, *et al.* 1991, Diaz and Rosenberg 1995). There were no seasons where hypoxia (< 2 mg/l) or anoxia (0 mg/l) were observed at these inland sites during the 14-yr monitoring program.

YEARLY SUMMARY OF MACROINFAUNAL ASSEMBLAGE

Yearly variation in general characteristics of the macroinfaunal assemblage for the Clovelly/freshwater intake stations is given in Fig. 9. Stations 461, 463, and 464 exhibited the same general patterns in total number of taxa, mean density, and mean diversity. There was a significant increase ($P < 0.05$) in the total number of taxa for all stations over the 14-yr monitoring period. This increase in total number of taxa was due to an artifact in the level of taxonomic precision at the BVA laboratories. Before 1983-84 the Oligochaeta (freshwater/brackish worms) and the Chironomidae (freshwater/brackish midges) were not identified to a lower taxonomic level. These groups were diverse and abundant at these brackish water stations. After 1983-84 these two taxonomic groups were further identified to genus and in some cases, species level. This change in the level of taxonomic precision led to an increase in number

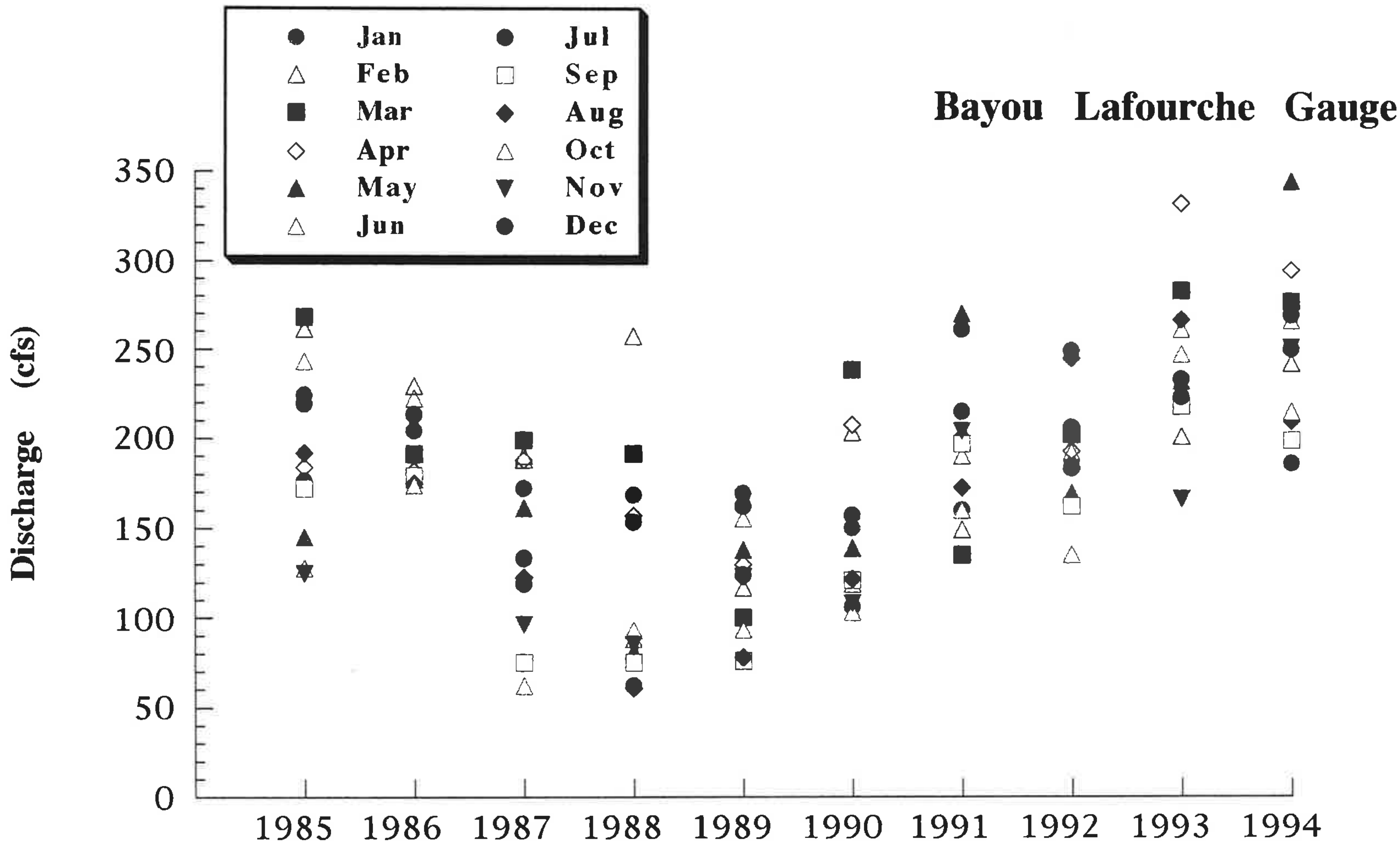


Figure 7. Mean monthly USGS discharge data for the Bayou Lafourche gauge, 1985-1994.

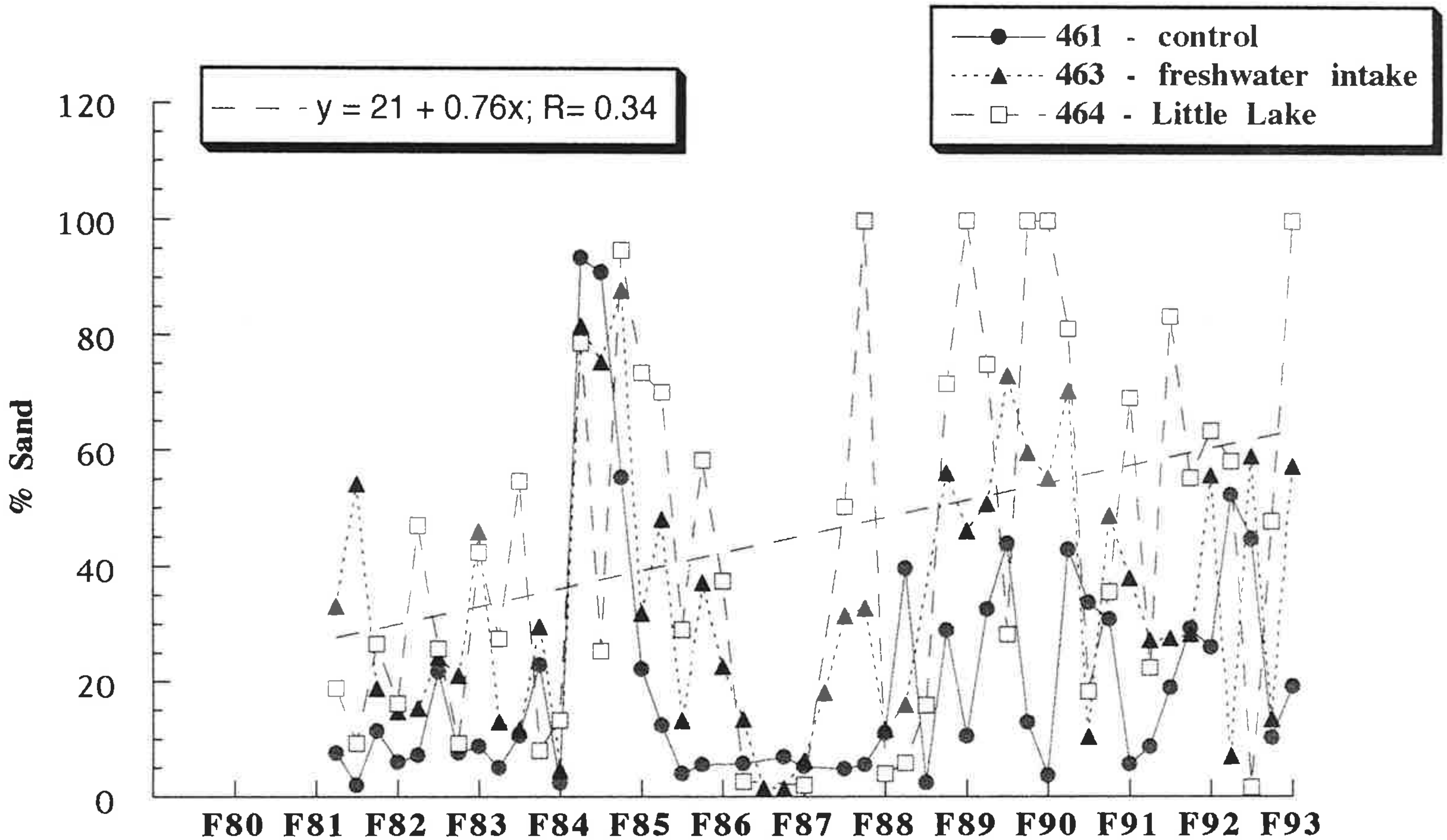


Figure 8. Yearly percent sand in the sediments for the inland Clovelly/freshwater intake control and monitoring stations. A plotted linear regression illustrates the trend of increasing percent sand in the sediments for monitoring station 464 at Little Lake.

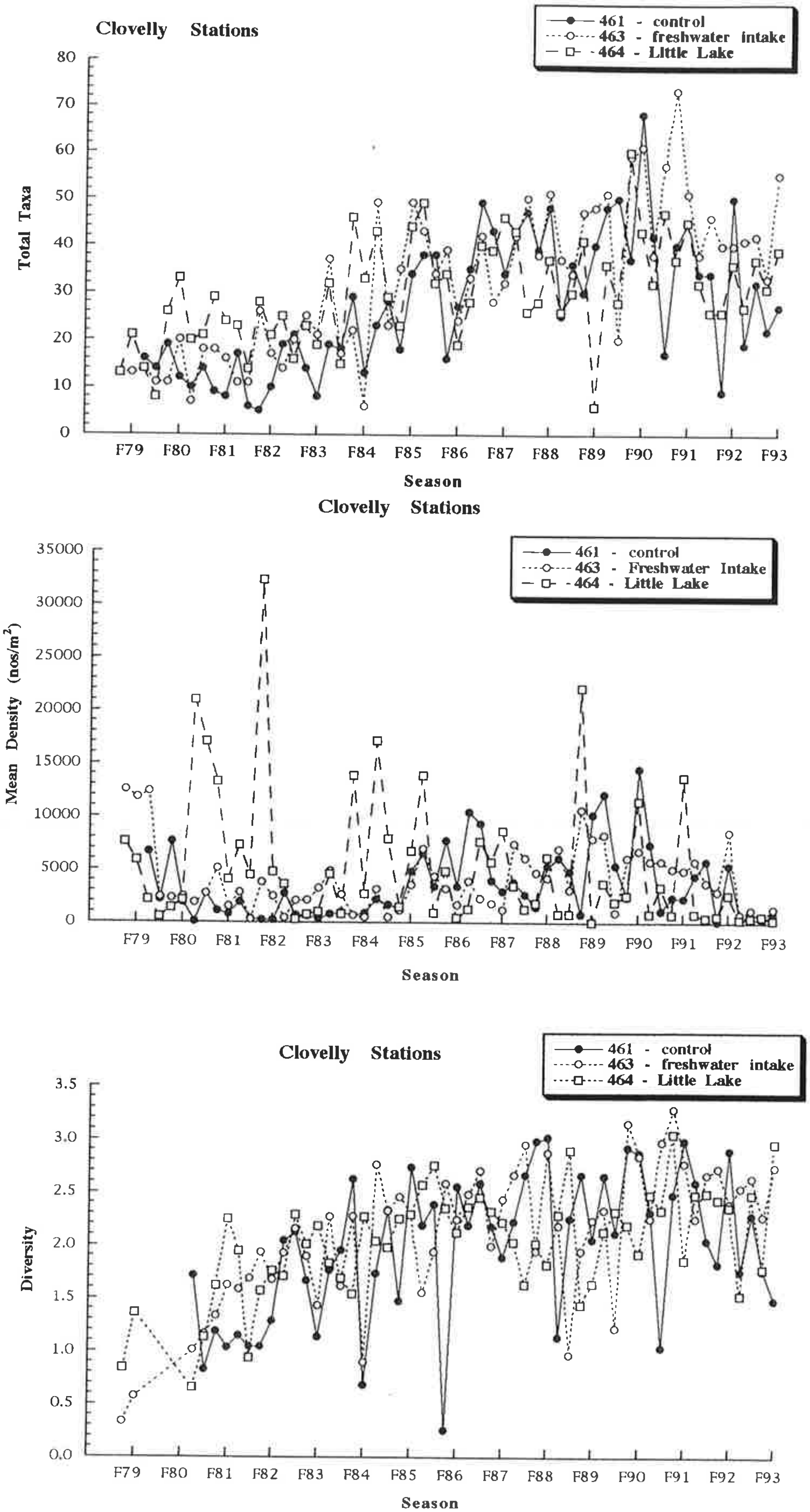
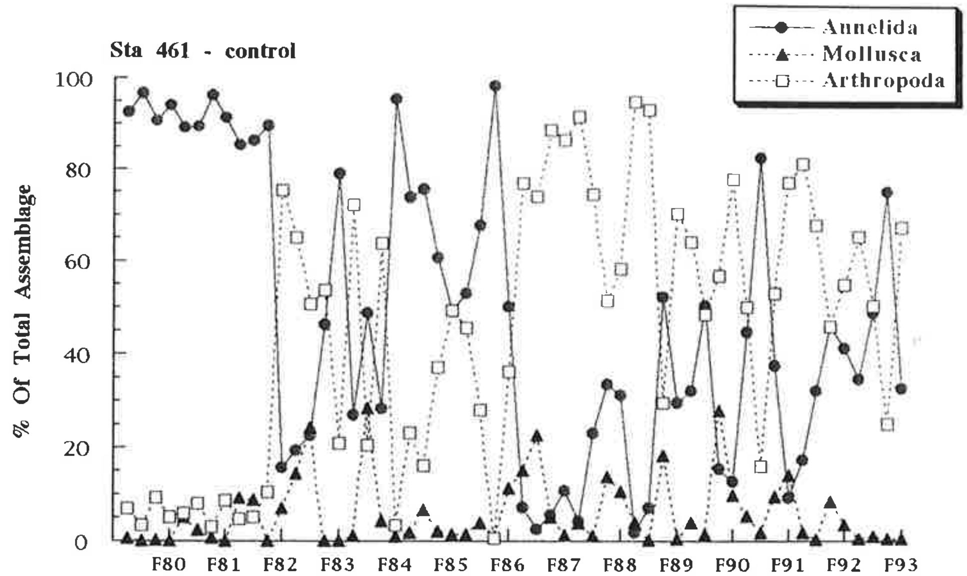


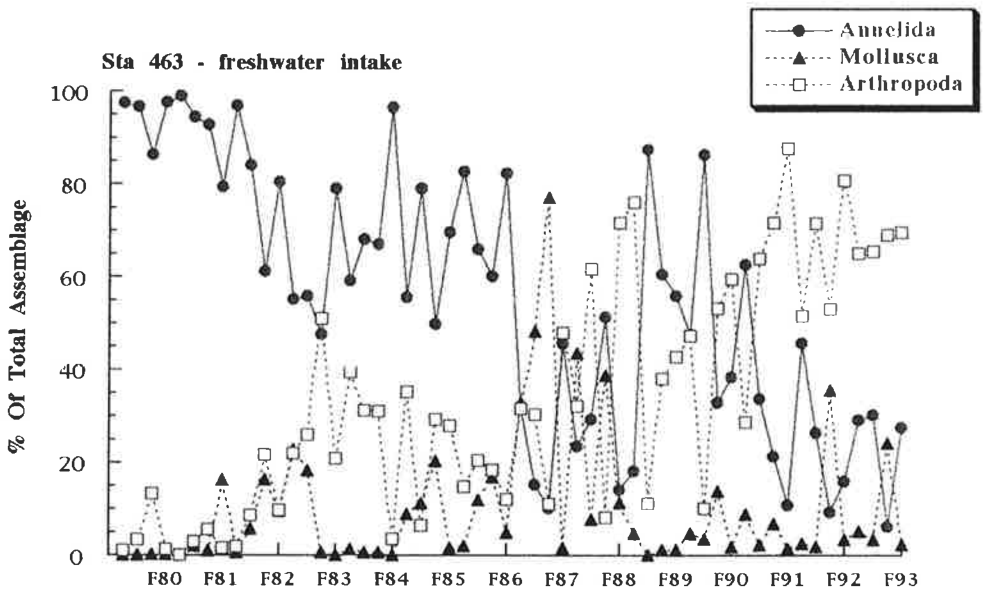
Figure 9. Yearly summaries of characteristics of the macroinfaunal assemblage over the 14-year LOOP monitoring program for the inland Clovelly/freshwater intake control and monitoring stations.

of taxa between 1984 and 1987. This taxonomic artifact can also be observed in the increase in species diversity from 1979 to 1985. Diversity measures are based on the relative abundance of species in the assemblage - a greater number of species, combined with no overall change in density, results in increased diversity. Considering the last 8 years of the monitoring program, total taxa ranged from < 10 to > 70 and mean diversity ranged from 1 to 3 at these stations (Fig. 9). The lowest numbers of taxa and lowest diversity occurred during the summer months. Mean densities exhibited similar patterns between stations. Densities ranged from < 1000 to > 32,000 individuals/m^2 (Fig. 9). Densities were generally higher and more variable on a seasonal basis at the Little Lake monitoring station. Highest densities occurred during the winter and spring months, while low densities were observed during the summer.

Yearly variation in abundance of the dominant taxonomic groups for stations 461, 463, and 464 is given in Fig. 10. Annelids (oligochaetes and some polychaetes), molluscs (bivalves), and arthropods (tubiculous amphipods and chironomids) generally made up > 95% of the total macroinfaunal assemblage during any given season. There was considerable seasonal and between station differences in the percentage of the assemblage represented by the three groups. Annelids and arthropods dominated stations 461 and 463 and there was a significant inverse correlation in their percentage composition (Table 4). The assemblages showed a change in community structure on a seasonal basis from a dominance by annelids (> 90%) to a dominance by arthropods (> 90%) over the 14-year monitoring program (Fig. 10). Station 464 exhibited seasonal dominance by all three taxonomic groups (Fig. 10). Station 461 demonstrated a weak statistical trend toward a gradual increase in arthropod abundance and a gradual decrease in annelid abundance over time (Fig. 11). Station 463 exhibited a similar significant statistical trend in taxonomic group replacement over time (Fig. 11). Station 464 showed a weak statistical trend in species replacement over time which included a gradual decrease in the abundance of bivalve molluscs (Fig. 11). These gradual changes in the macroinfaunal assemblage may have been due to changes in sediment composition at the three stations towards a coarser, more sandy sediment, which is the preferred habitat of tubiculous amphipods.

Yearly variation in abundance of dominant taxa for stations 461 and 463 is given in Figs. 12 and 13. The taxa/species chosen for each plot were dominant members of the macroinfaunal assemblage over the 14-year sampling effort at each station. Taxa/species plotted were Oligochaeta (an annelid class), the polychaetes *Mediomastus*, *Streblospio*, and *Hobsonia*, the family Chironomidae (a dipteran), and the amphipods *Corophium* and *Grandidierella*. There was considerable spatial and temporal variation in densities of dominant taxa/species (Figs. 12 and 13). The oligochaetes and polychaetes exhibited seasonal and year-to-year variation in recruitment at both stations (Figs. 12





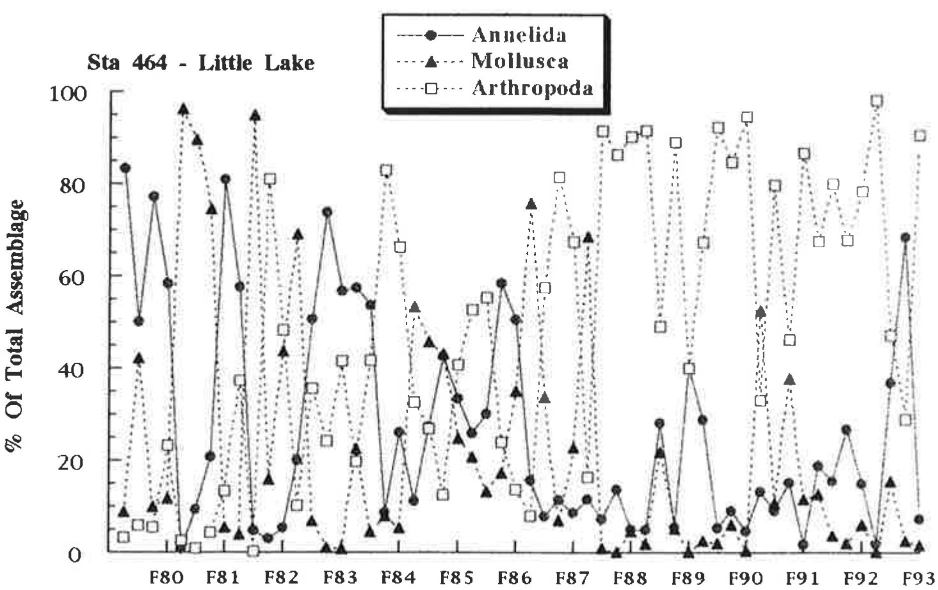
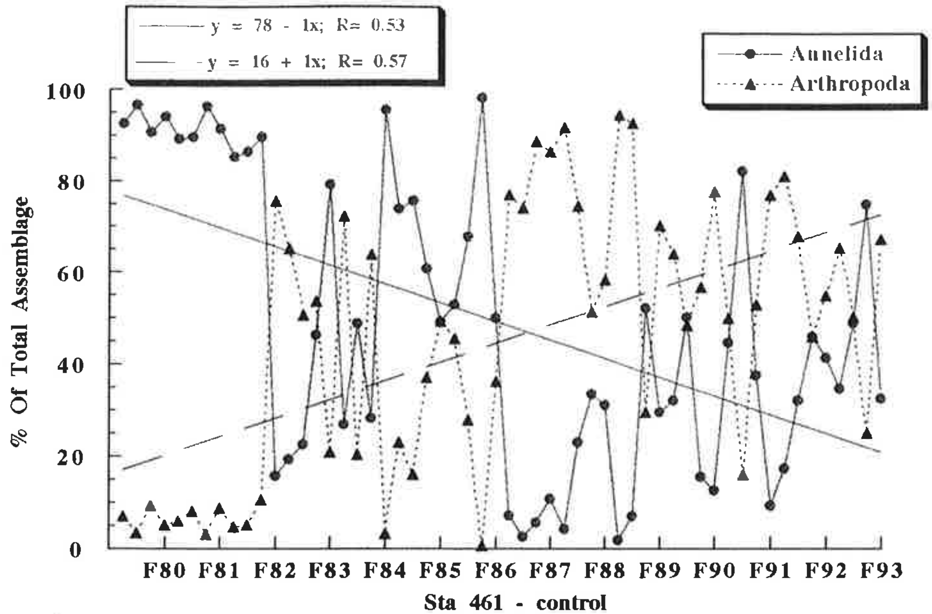
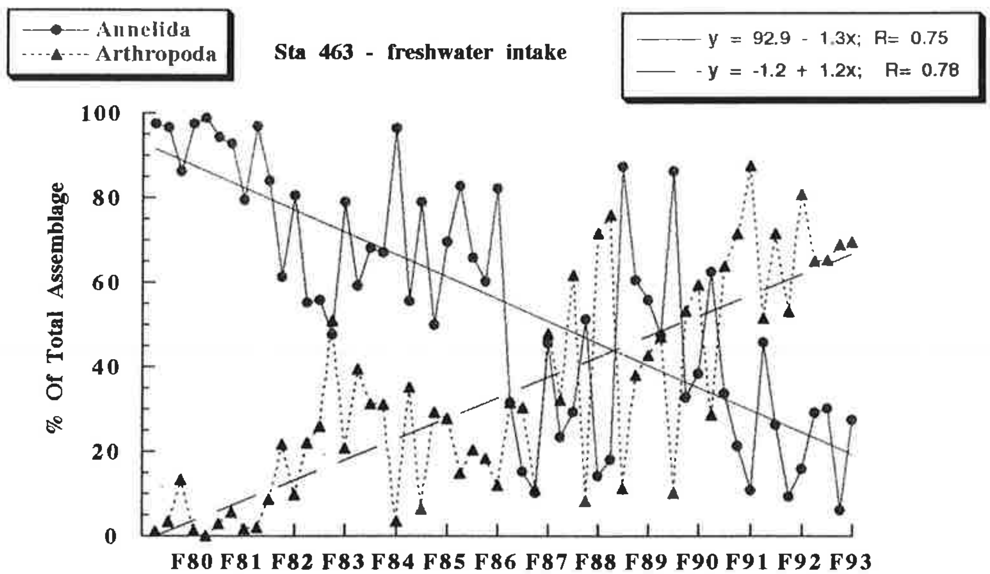


Figure 10. Yearly summaries for the percentage of the total macroinfauna assemblage represented by the major taxonomic groups, Annelida, Mollusca, and Arthropoda over the 14-year LOOP monitoring program for the inland Clovelly/freshwater intake control and monitoring stations.





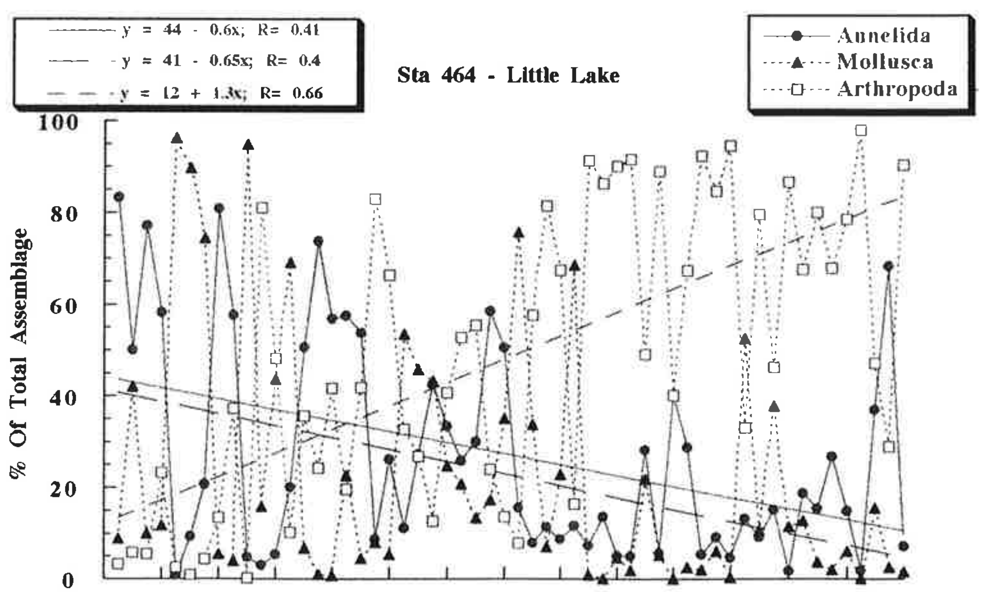
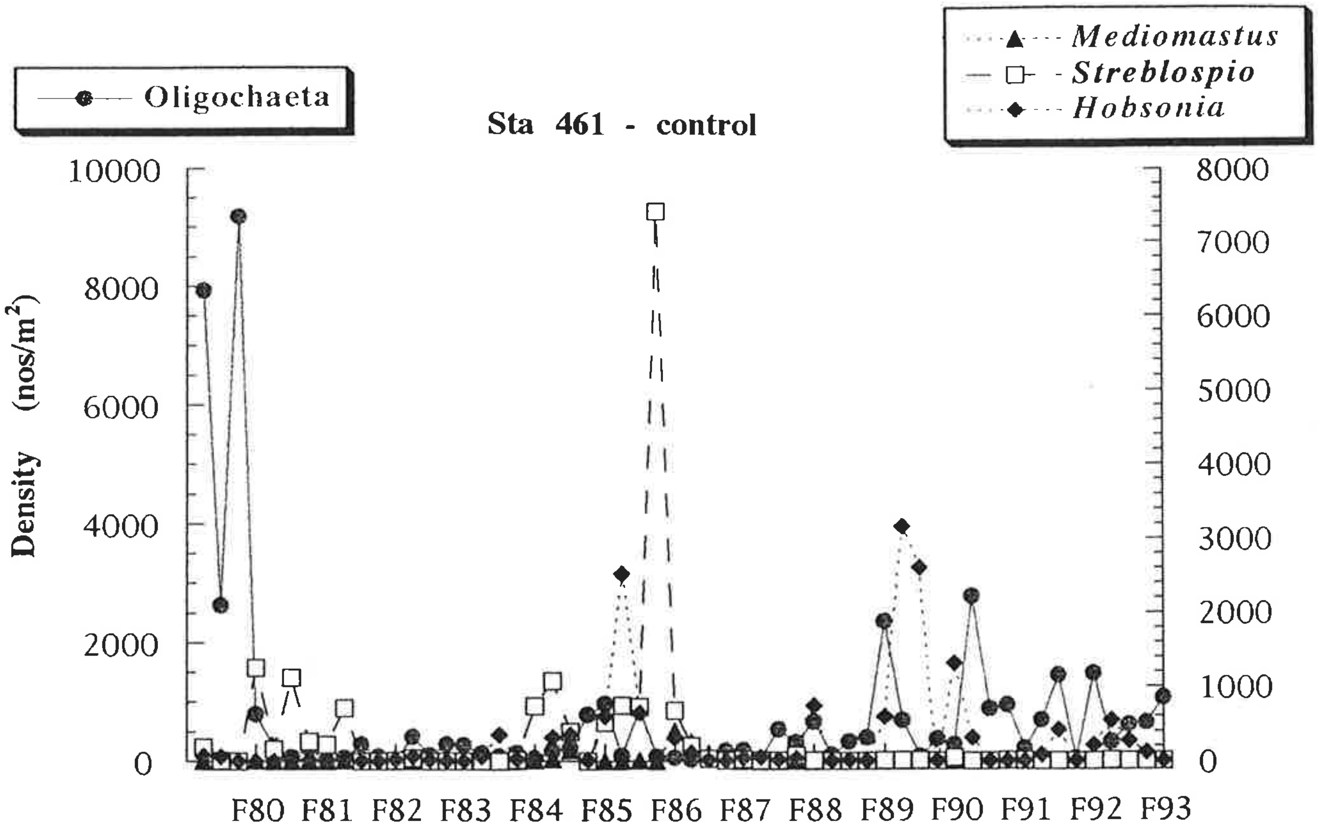


Figure 11. Yearly summaries for the percentage of the total macroinfauna assemblage represented by the major taxonomic groups over the 14-year LOOP monitoring program for the inland Clovelly/ freshwater intake control and monitoring stations. Regression lines indicate changes in the abundance of the dominant taxonomic groups over the LOOP monitoring program.



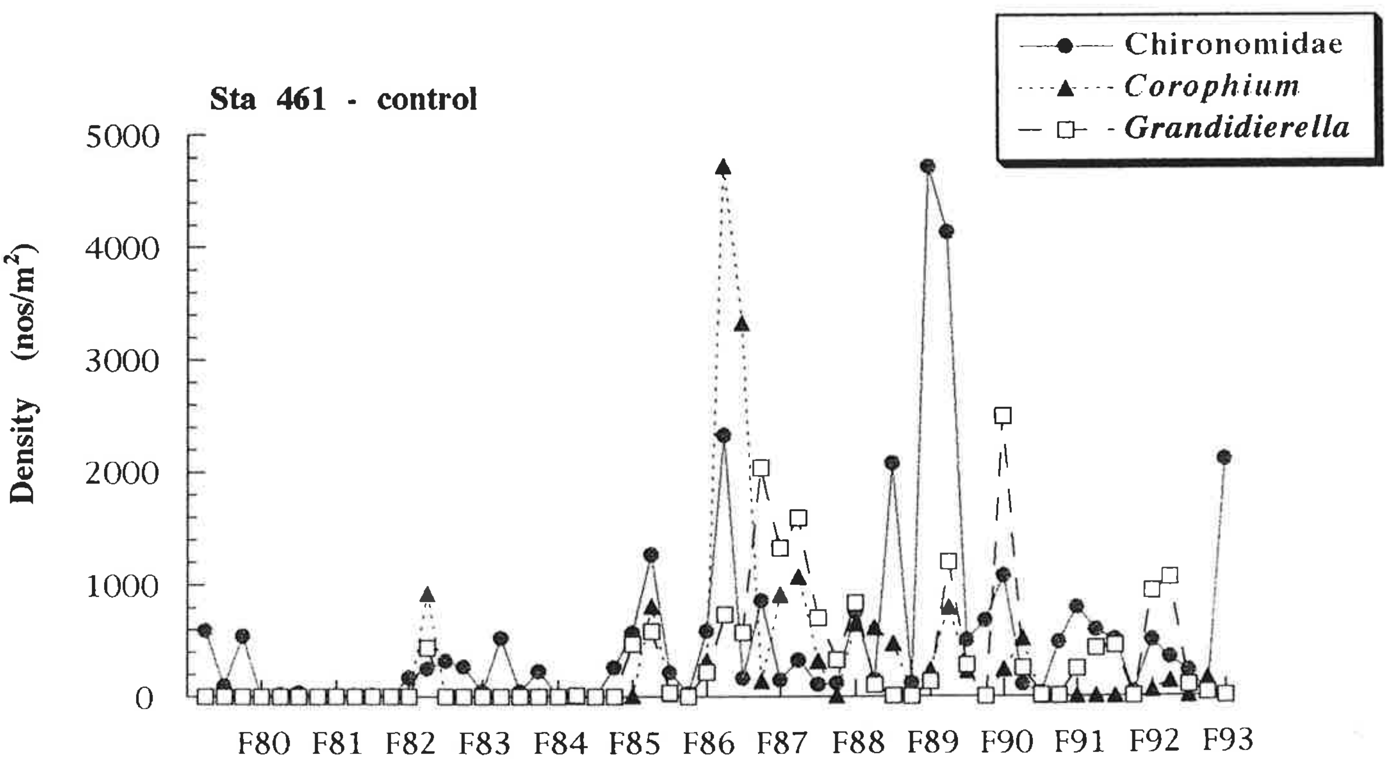
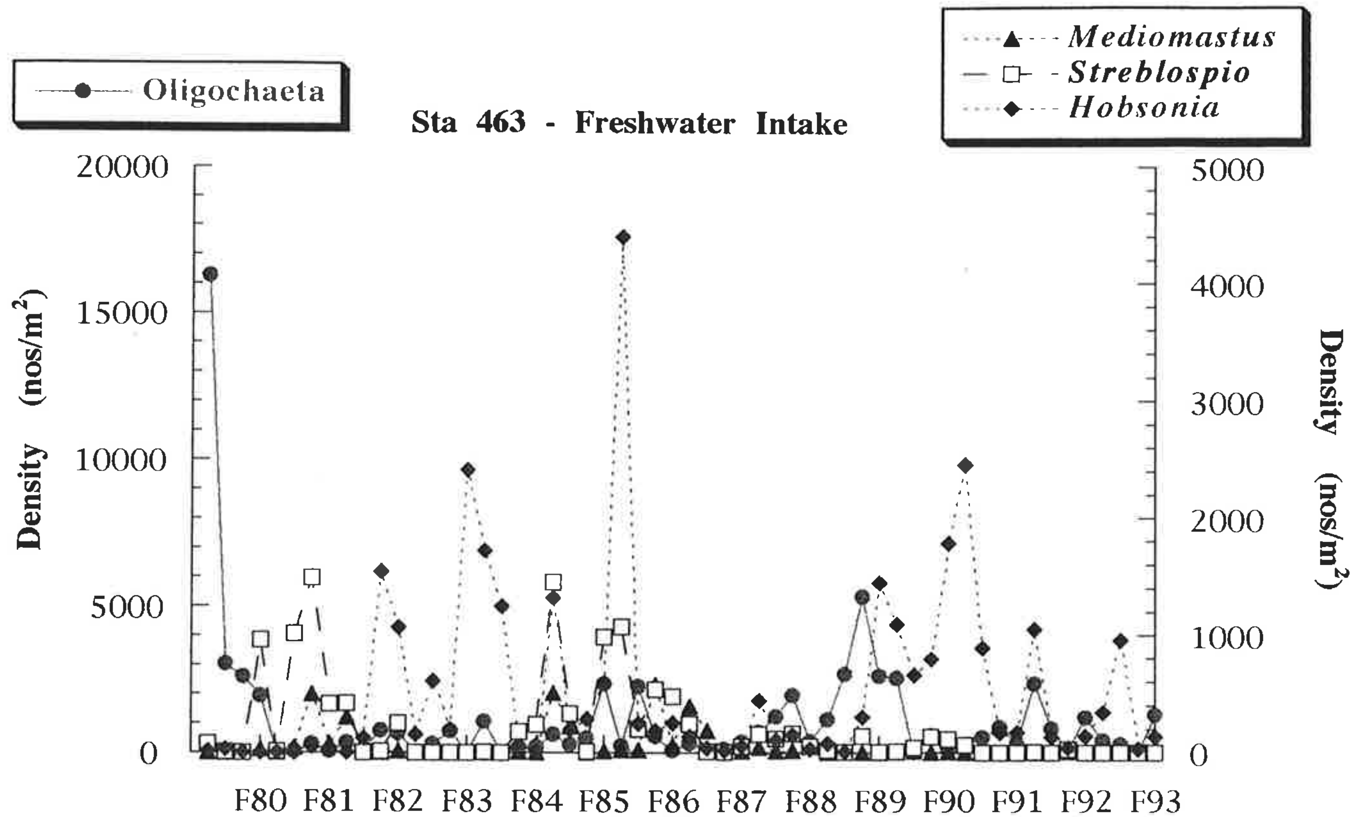


Figure 12. Yearly density summaries of dominant taxa/species for the Clovelly station 461.



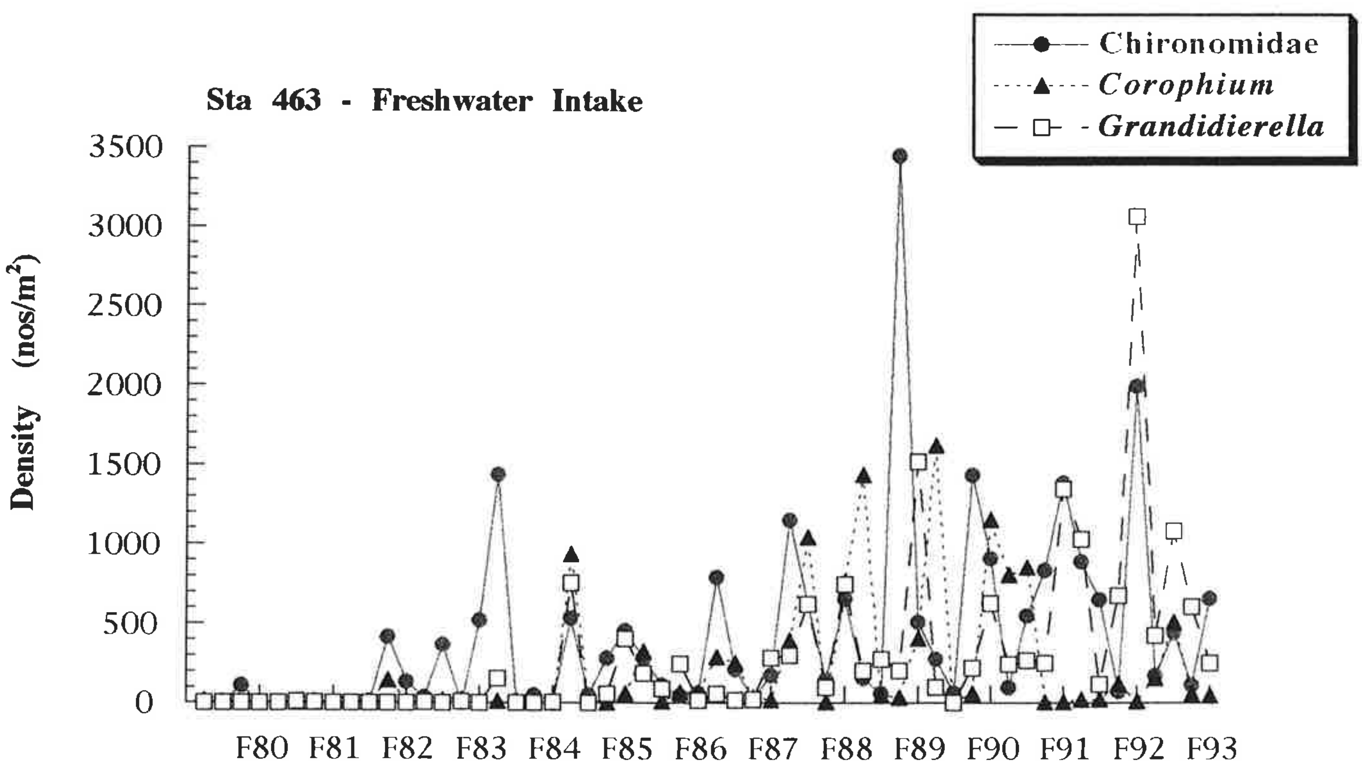


Figure 13. Yearly density summaries of dominant taxa/species for the Clovelly freshwater intake monitoring station 463.

and 13). Additionally, there was differential recruitment success for these taxa on a yearly basis; densities often varied an order of magnitude annually. These localized spatial differences in taxa abundance and temporal variation in recruitment success are commonly found in estuarine and marine benthic communities. There was a pronounced increase in the abundance of amphipod species over the monitoring period (Figs. 12 and 13). *Grandidierella* and *Corophium* became dominant members of the macroinfaunal community in 1985. It is interesting to note that this increase in amphipod abundance occurred in the years following hurricane Juan and a gradual change in sediment texture.

A comparison of densities of *Hobsonia*, *Grandidierella*, and *Chironomidae* for control station 461 and monitoring station 463 is given in Fig. 14. There were significant positive correlations in densities of the three taxa between stations 461 and 463 (Table 4). While the patterns of taxa abundance were similar between stations, there were qualitative differences in abundance during a given season (Fig. 14).

RESULTS II. INLAND PIPELINE MONITORING STATIONS AT LAKE JESSE

SEASONAL SUMMARY OF HYDROGRAPHY

A seasonal summary of hydrographic characteristics for pipeline monitoring stations 407 and 462 is given in Fig. 15. There was considerable spatial and temporal variation in the percentage of sand in the sediments at the three stations. The percentage of sand in the sediment varied from 11% at control station 407 in the summer to 25% at pipeline monitoring station 462 in the winter. The average percent sand was 17% and 21% for stations 407 and 462, respectively. There were no spatial or temporal differences in interstitial salinity. Interstitial salinity averaged 28 ppt for the two stations and ranged from 15 ppt in the winter at control station 407 to 19 ppt at pipeline monitoring station 462 during the spring, summer and fall (Fig. 15). Bottom dissolved oxygen exhibited considerable temporal variability and was highest during the winter and fall sampling periods and lowest during the spring and summer (Fig. 15). There were no differences between stations in bottom dissolved oxygen.

SEASONAL SUMMARY OF MACROINFAUNAL ASSEMBLAGE

A seasonal summary of the general characteristics of the macroinfauna assemblage for the pipeline monitoring stations 407 and 462 is given in Fig. 16. There were no significant differences between average number of taxa collected and mean total density at the four stations for a given season (Table 5). The mean number of taxa collected were 34.2, 24.4, 25.5, and 29.4 for the winter, spring, summer, and fall seasons, respectively (Fig. 16).

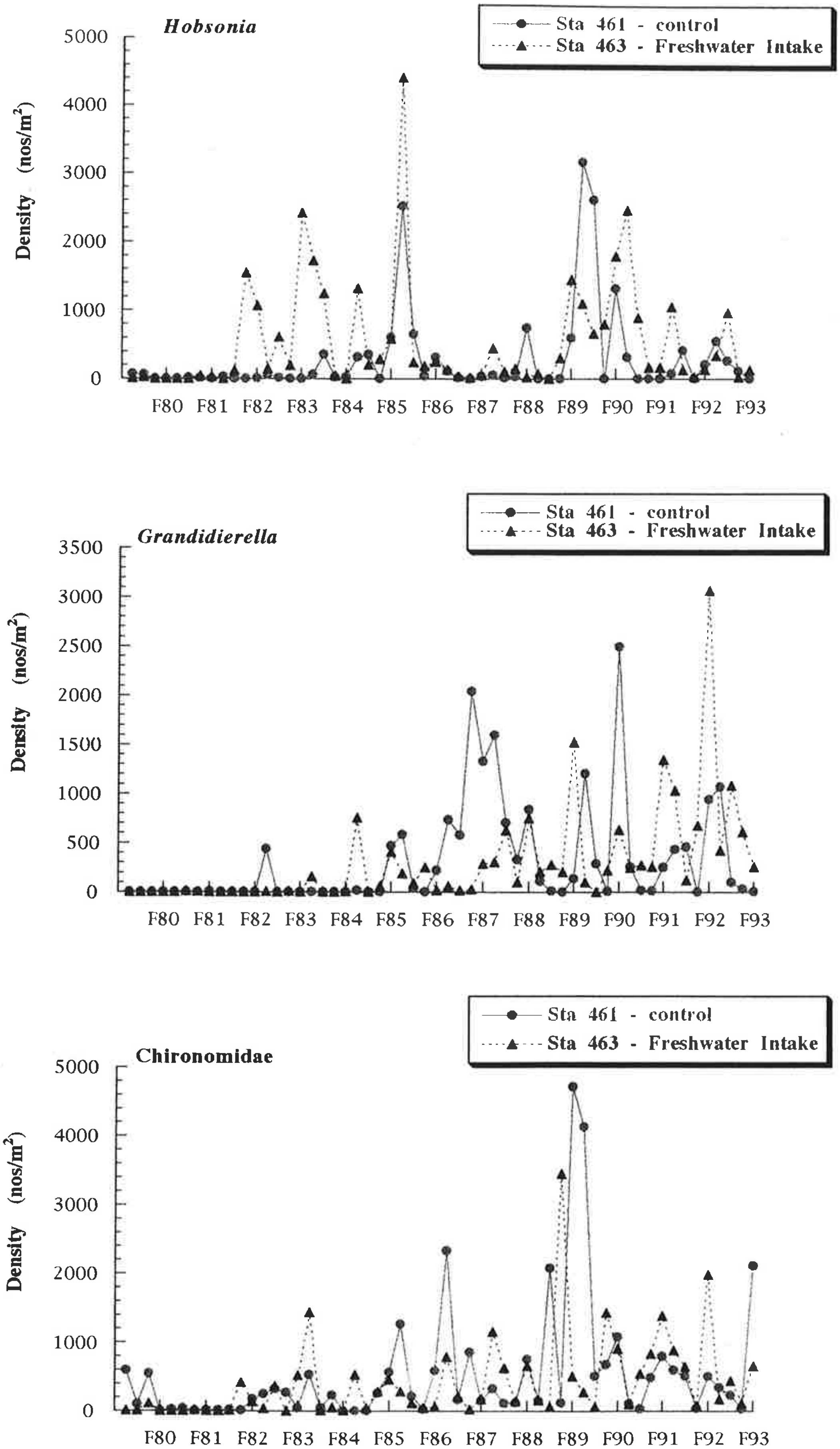


Figure 14. A comparison of yearly densities of the polychaete *Hobsonia*, the amphipod *Grandidierella*, and the Chironomidae for Clovelly control station 461 and the Clovelly freshwater intake monitoring station 463.

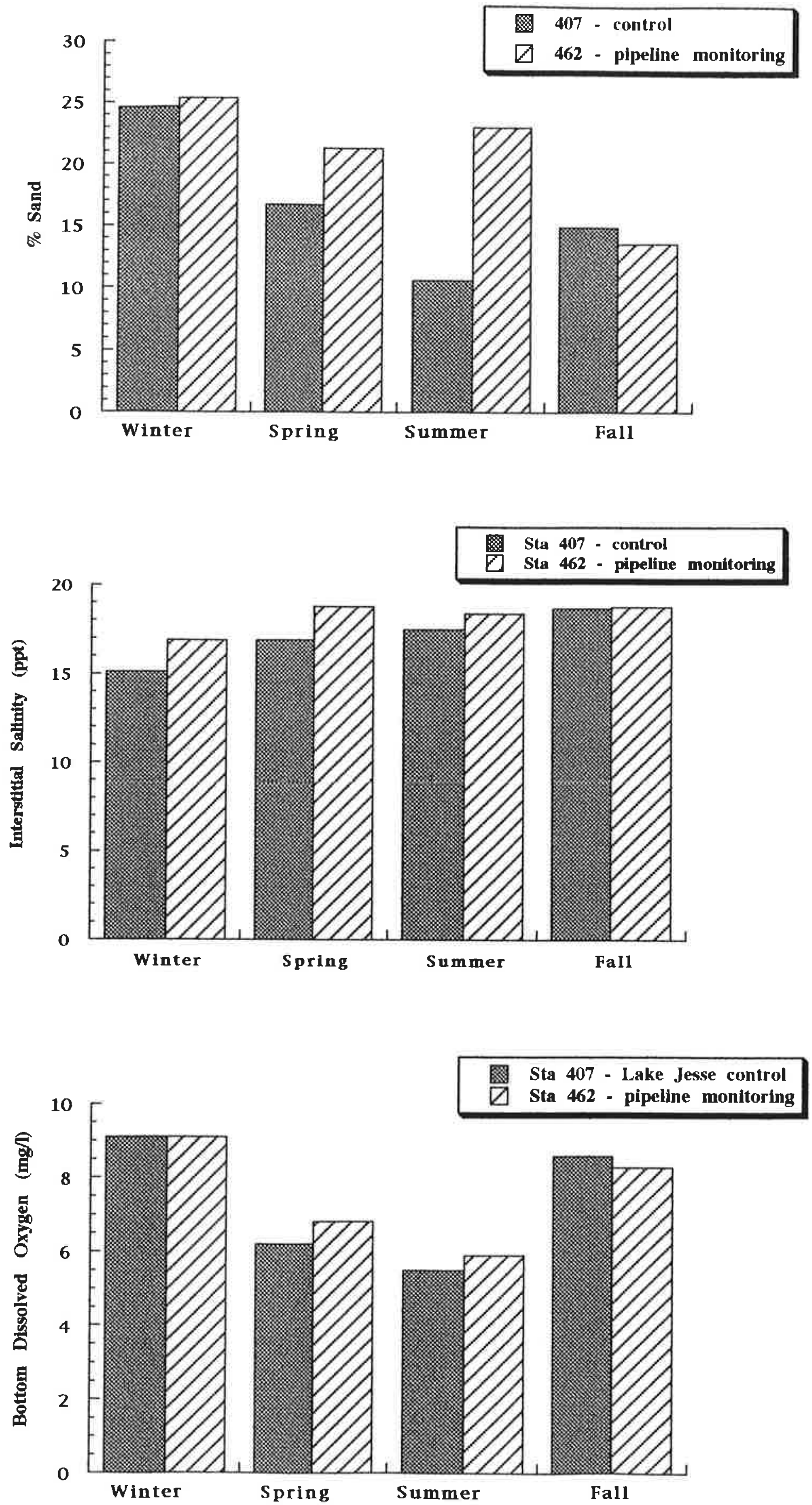


Figure 15. Seasonal summaries of hydrographic parameters over the 14-year LOOP monitoring program for the inland pipeline control and monitoring stations at Lake Jesse.

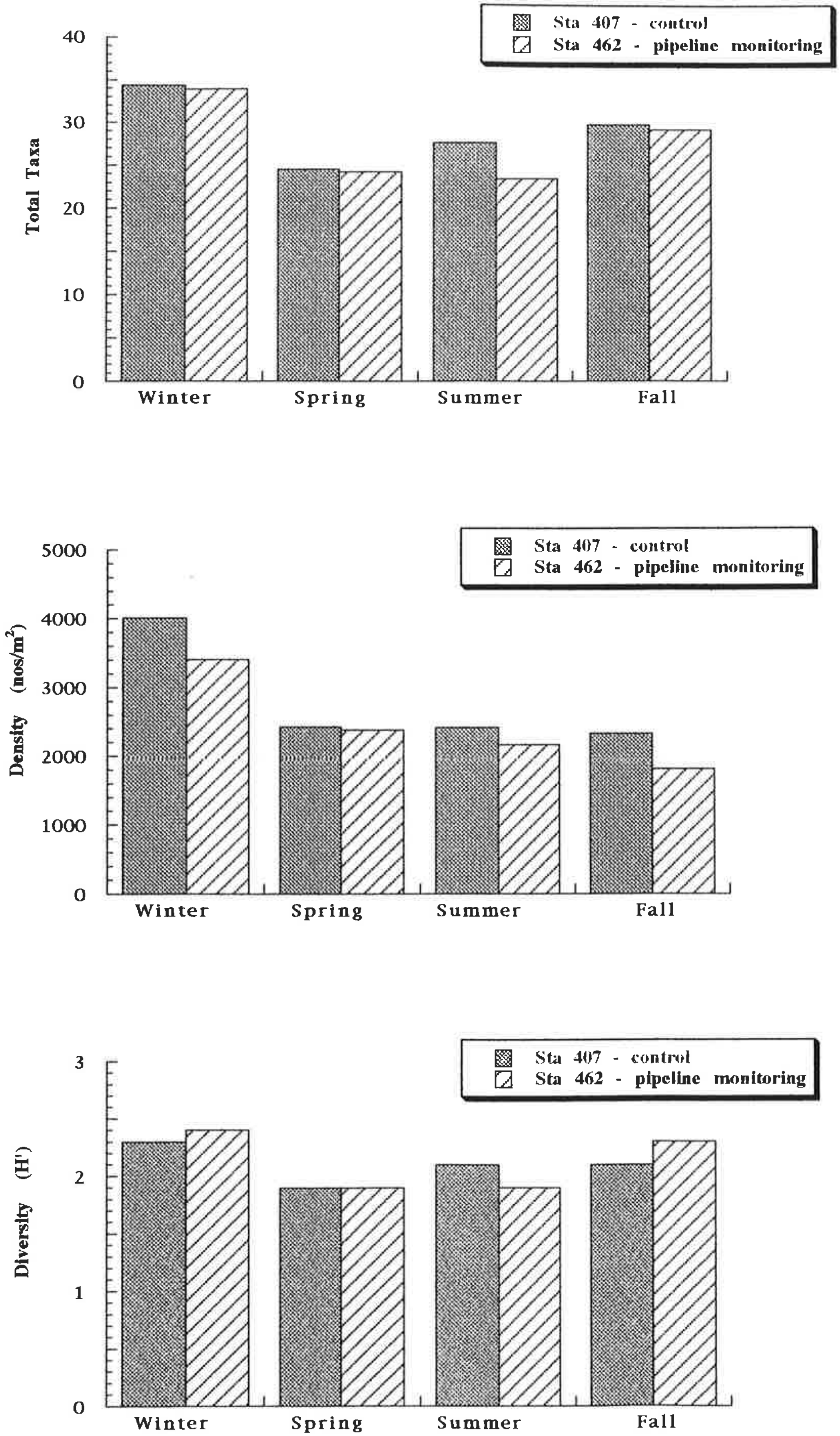


Figure 16. Seasonal summaries of characteristics of the macroinfaunal assemblage over the 14-year monitoring program for the inland pipeline control and monitoring stations at Lake Jesse.

Table 5. Results of various statistical analyses for the LOOP inland pipeline control and monitoring stations at Lake Jesse. The results of non-parametric Wilcoxon comparisons of total number of taxa or mean density between stations for a given season are presented in Part A. The results of non-parametetric analyses for correlations between stations in major taxonomic groups is given in Part B. The results of non-parametetric analyses for correlations between stations in major taxa/species is given in Part C.

(A)

Season	Mean Total Taxa		Mean Density	
	Chi Square	Prob > Chi Sq	Chi Square	Prob > Chi Sq
Winter	.053	0.818	0.000	1.000
Spring	.001	.982	0.304	0.581
Summer	1.609	0.205	.357	0.550
Fall	.053	0.818	1.965	0.161

(B)

Station	Variable	by	Station	Variable	Spearman Rho	Prob > Rho
407	Mollusca		407	Annelida	-0.6373	0.0000
407	Arthropoda		407	Annelida	-0.5182	0.0000
407	Arthropoda		407	Mollusca	-0.0314	0.8185
462	Mollusca		462	Annelida	0.6558	0.0000
462	Arthropoda		462	Annelida	-0.8168	0.0000
462	Arthropoda		462	Mollusca	0.2114	0.1178

(C)

Station	Variable	by	Station	Variable	Spearman Rho	Prob > Rho
462	*Mediomastus*		407	*Mediomastus*	0.6155	0.0000
462	*Ampelisca*		407	*Ampelisca*	0.5104	0.0001

Densities were highest during the winter months (3708.4 individuals/m^2) and averaged 2255.4 individuals/m^2 for the remaining seasons. There was little between station variation in diversity (H') and diversity averaged 2.4, 1.9, 2.0, and 2.2 for the winter, spring, summer, and fall seasons, respectively (Fig. 16).

YEARLY SUMMARY OF HYDROGRAPHY

Yearly variation in hydrography for the pipeline monitoring stations 407 and 462 is given in Fig. 17. There was considerable temporal variation in the percentage of sand in the sediments at the two stations and ranged from near zero to 90%. Seasonal peaks in percent sand appeared to correspond with seasonal periods of high discharge. There was a pronounced increase in the amount of sand in the sediments after 1984 for control station 407 and generally remained higher than station 462 for the remainder of the monitoring period (Fig. 17). As noted previously, hurricane Juan made landfall near these stations in the fall of 1985 and may have been responsible for the change in sediment texture.

Interstitial salinity values were not measured at stations 407 and 462 until the 1984 sampling season. Interstitial salinities exhibited similar seasonal patterns between stations and generally varied between 15 ppt and 25 ppt (Fig. 17). Low salinity events (< 10 ppt) occurred during 1984, 1985-86, 1990, 1991, and 1993. It is possible that these low salinity events were caused by high seasonal discharge (Fig. 7).

Bottom dissolved oxygen (DO) levels showed considerable temporal variation ranging from > 2 to 13 mg/l (Fig. 17). Stations 407 and 462 had similar temporal patterns in DO levels. The lowest DO levels occurred during the summer and fall months, while the highest levels were measured during the winter (Fig. 17). There were no seasons when hypoxia (< 2 mg/l) or anoxia (0 mg/l) were observed at these sites during the 14-yr monitoring program. Bottom DO at both stations approached 2 mg/l during the summer of 1982 (Fig. 17).

YEARLY SUMMARY OF MACROINFAUNAL ASSEMBLAGE

Yearly variation in general characteristics of the macroinfaunal assemblage for the pipeline monitoring stations 407 and 462 is given in Fig. 18. These stations exhibited the same general temporal patterns in total number of taxa, mean density, and mean diversity. Total taxa showed considerable seasonal and annual variation and ranged from < 10 to > 50. The total number of taxa was generally highest in the winter and spring months and lowest during the summer months. Mean densities varied three orders of magnitude between season and from year-to-year and ranged from < 100 to > 11,000 individuals/m^2 indicating differential recruitment success of taxa in the macroinfaunal assemblage (Fig. 18). Densities were generally highest during the winter and spring months, while lower densities

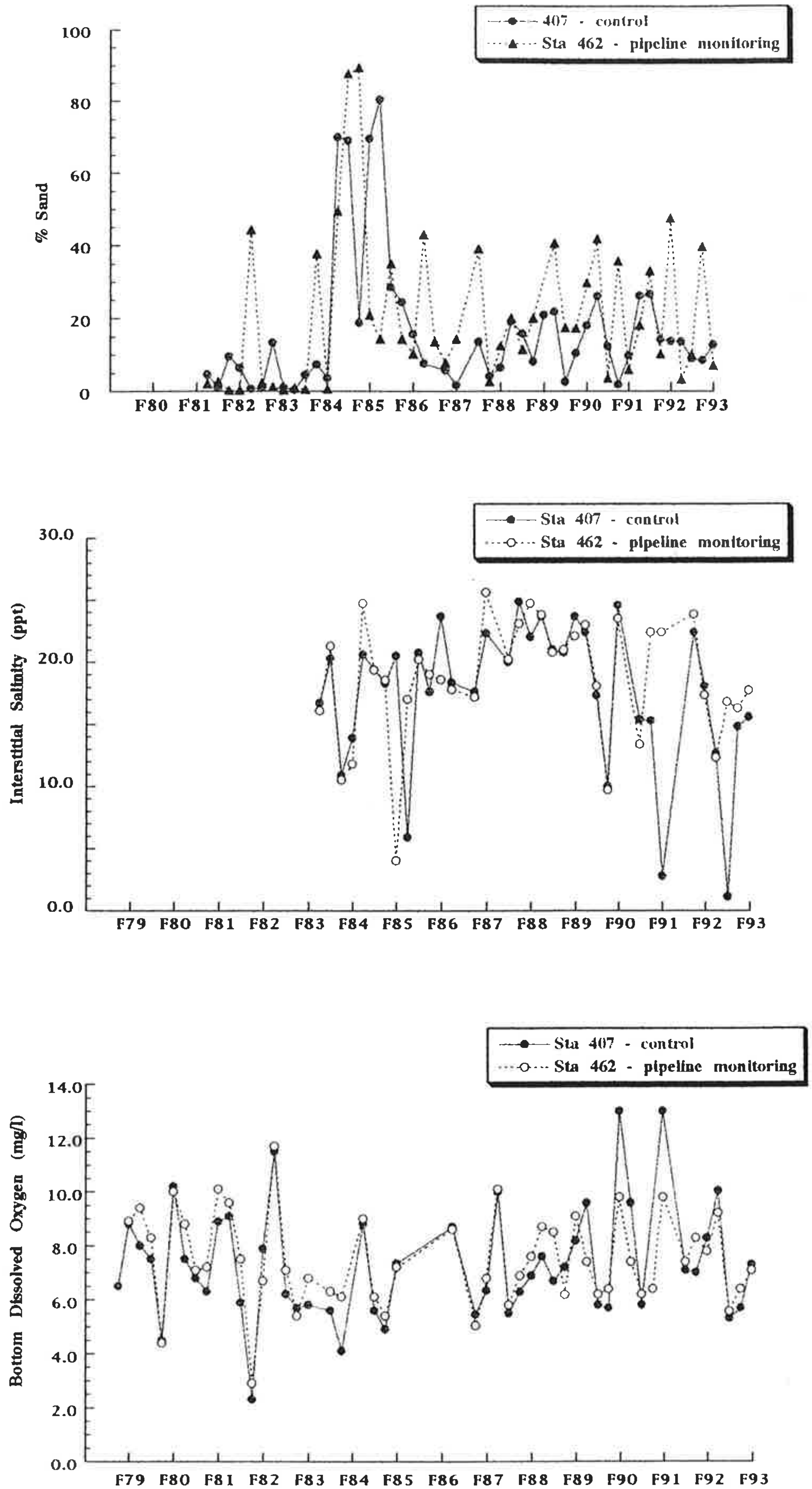
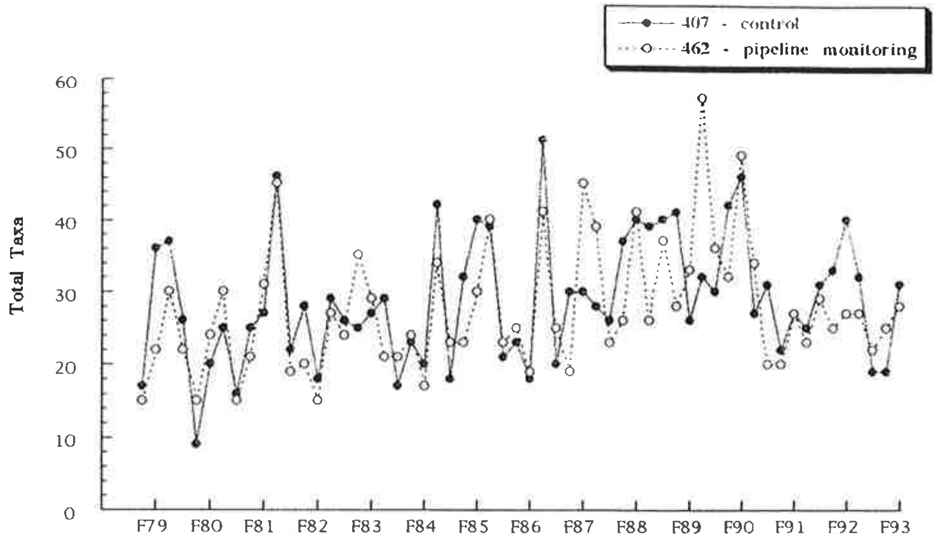
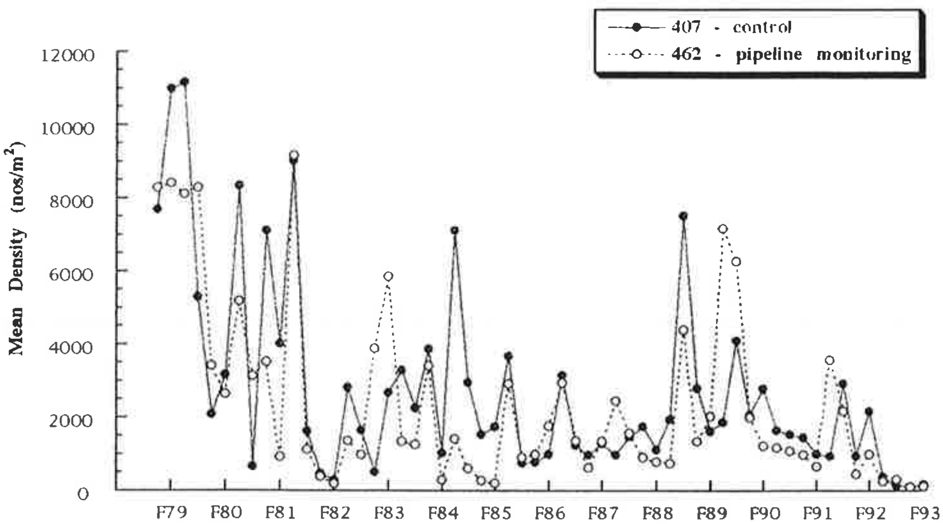


Figure 17. Yearly summaries of hydrographic parameters over the 14-year monitoring program for the inland pipeline control and monitoring stations at Lake Jesse.





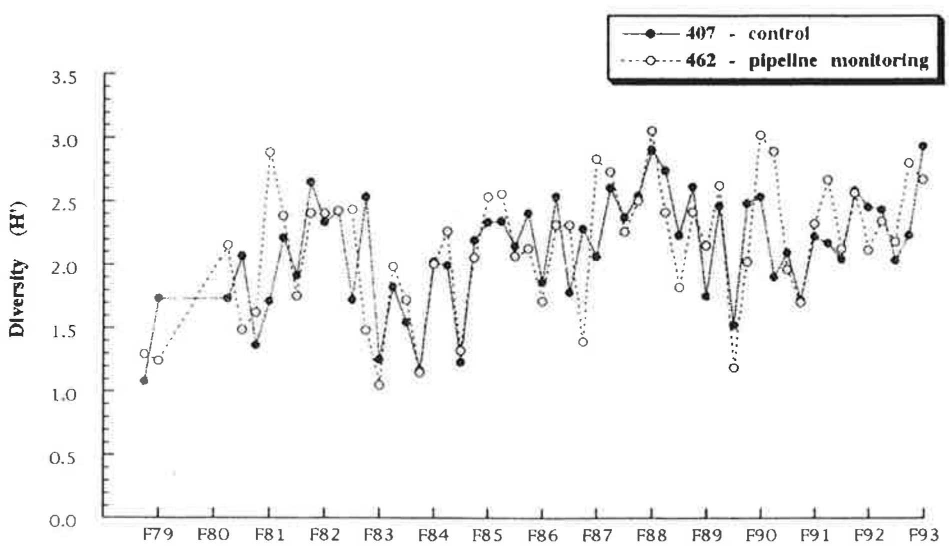


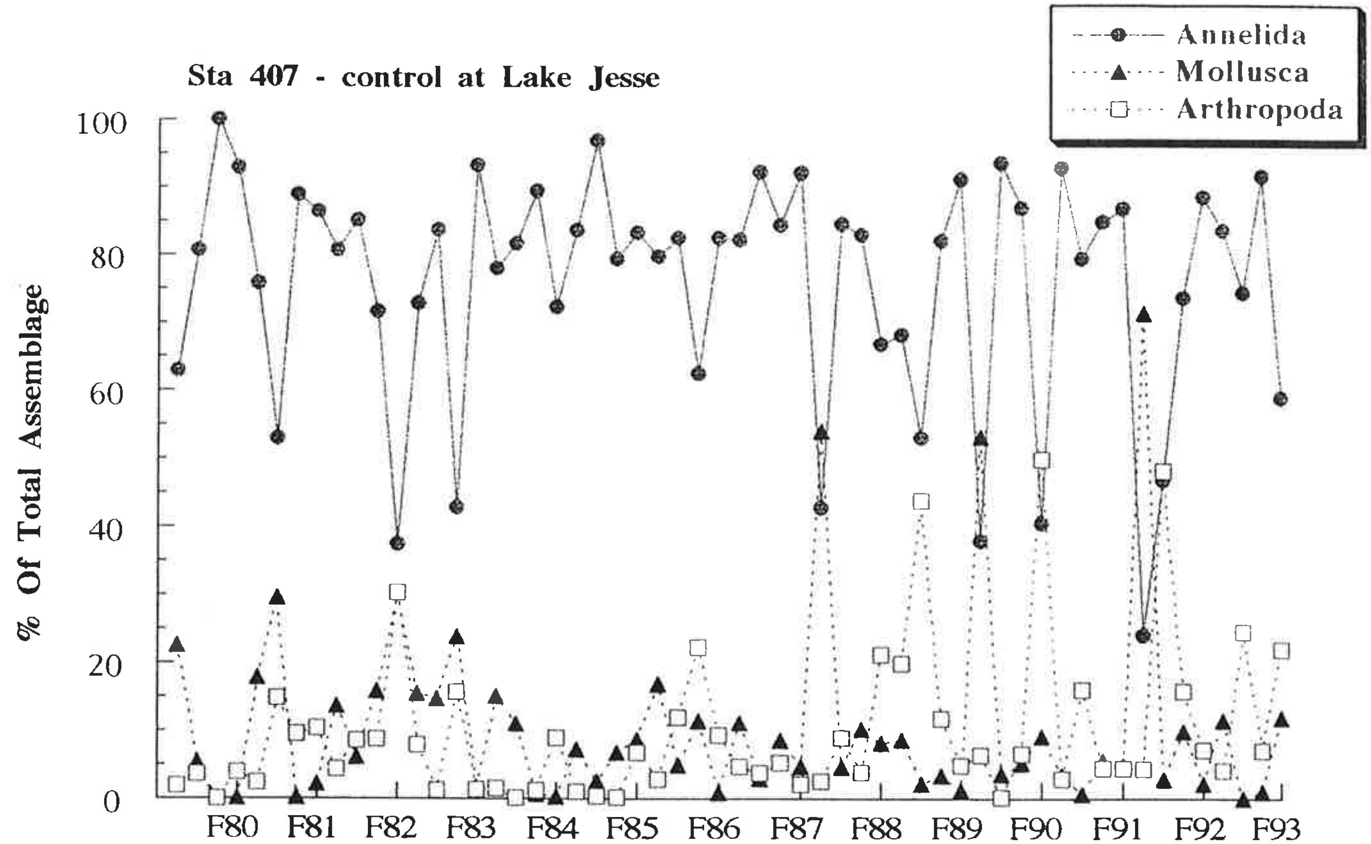
Figure 18. Yearly summaries of characteristics of the macroinfaunal assemblage over the 14-year monitoring program for the inland pipeline control and monitoring stations at Lake Jesse.

were observed during the summer and fall. Taxa diversity ranged from 1 to 3 and was highest in the winter and spring months, and lowest during the summer. There was a trend (not statistically significant) towards increasing numbers of taxa and taxa diversity over the first 7 years of the monitoring program (Fig. 18). As discussed earlier, this trend was due to increasing taxonomic precision in the data analysis. The trend was not as pronounced in these stations due to the reduced abundance of chironomids in the samples.

Yearly variation in abundance of the dominant taxonomic groups for stations 407 and 462 is given in Fig. 19. Annelids (polychaetes and some oligochaetes), molluscs (bivalves), and arthropods (tubiculous amphipods) generally made up > 90% of the total macroinfaunal assemblage during any given season. There was considerable seasonal and between station differences in the percentage of the assemblage represented by the three groups. In general, annelids dominated the assemblage at both stations. There were episodic increases in the percent abundance of molluscs and arthropods resulting in shifts in dominance of the taxonomic groups during certain years (Fig. 19). There was a significant inverse correlation between the abundance of both annelids and molluscs and annelids and arthropods for stations 407 and 462 (Table 5).

Yearly variation in abundance of dominant taxa for stations 407 and 462 is given in Figs. 20 and 21. The taxa/species chosen for each plot were dominant members of the macroinfaunal assemblage at these sites over the 14-year sampling effort. Taxa/species plotted were Oligochaeta (an annelid order), the polychaetes *Mediomastus* and *Streblospio*, the bivalve molluscs *Mulinia* and *Tellina*, and the amphipods, *Corophium* and *Ampelisca*. There was considerable spatial and temporal variation in densities of these dominant taxa/species (Figs. 20 and 21). The taxa/species exhibited season-to-season and year-to-year variation in recruitment at both stations (Figs. 20 and 21). Additionally, there was differential recruitment success for these taxa on a yearly basis; densities often varied an order of magnitude on an annual basis. In particular, the bivalves and amphipods demonstrated episodic increases in density over the 14-year monitoring period. There was no apparent correlation between density increases and season for the taxa/species. These data indicate the importance of long-term monitoring for determining limits to the abundance of macroinfaunal species.

A comparison of densities of the polychaete, *Mediomastus*, and the amphipod, *Ampelisca* for control station 407 and monitoring station 462 is given in Fig. 22. There was a significant positive correlation between the densities of *Mediomastus* and *Ampelisca* at stations 407 and 462 (Table 5). While the patterns of taxa abundance were similar



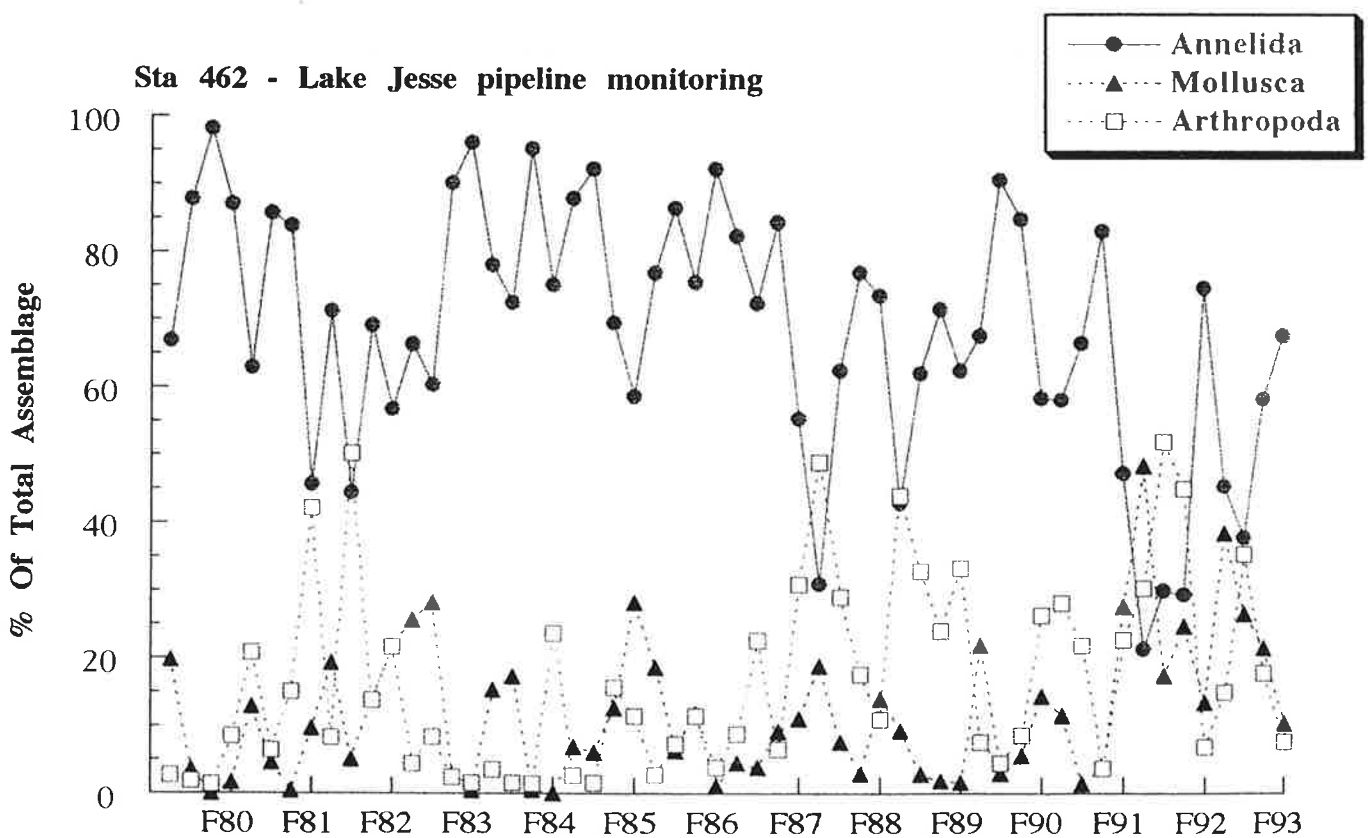
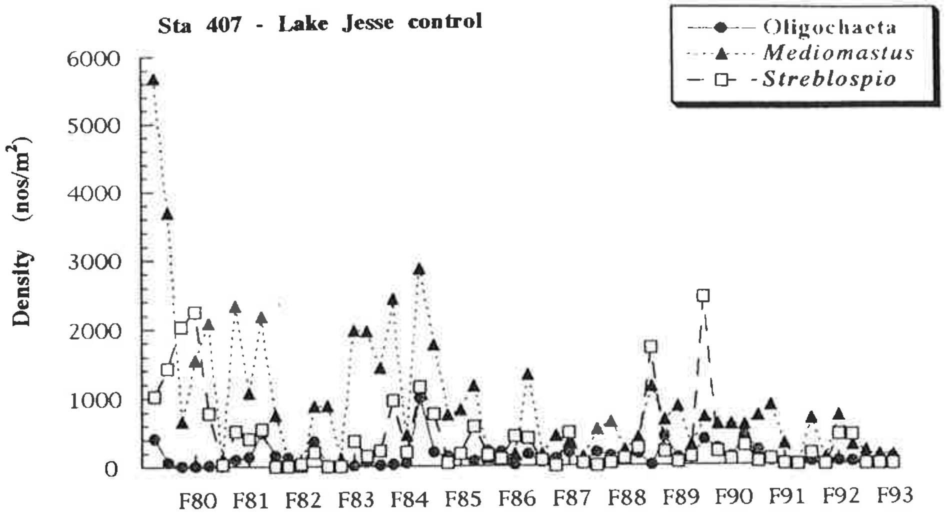
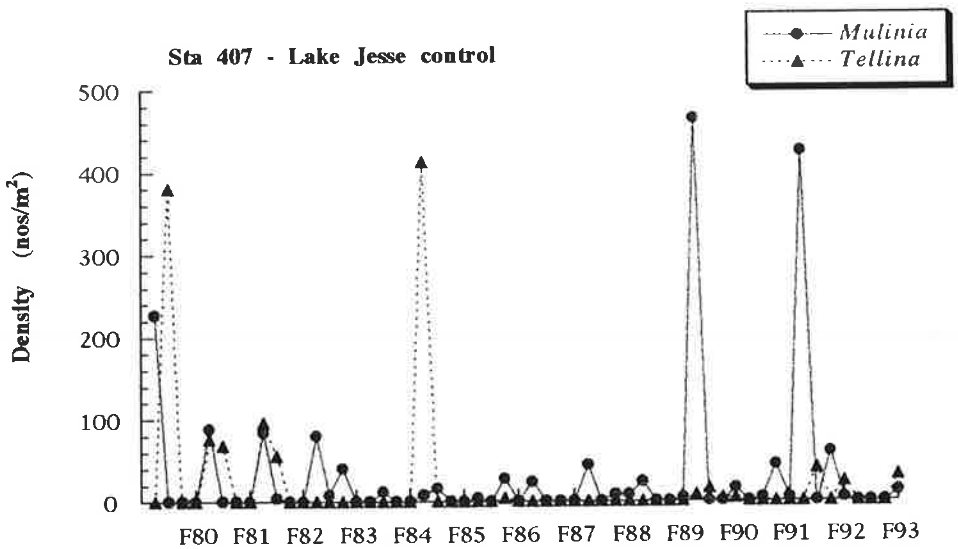


Figure 19. Yearly summaries for the percentage of the total macroinfauna assemblage represented by the major taxonomic groups, Annelida, Mollusca, and Arthropoda over the 14-year LOOP monitoring program for the inland pipeline control and monitoring stations at Lake Jesse





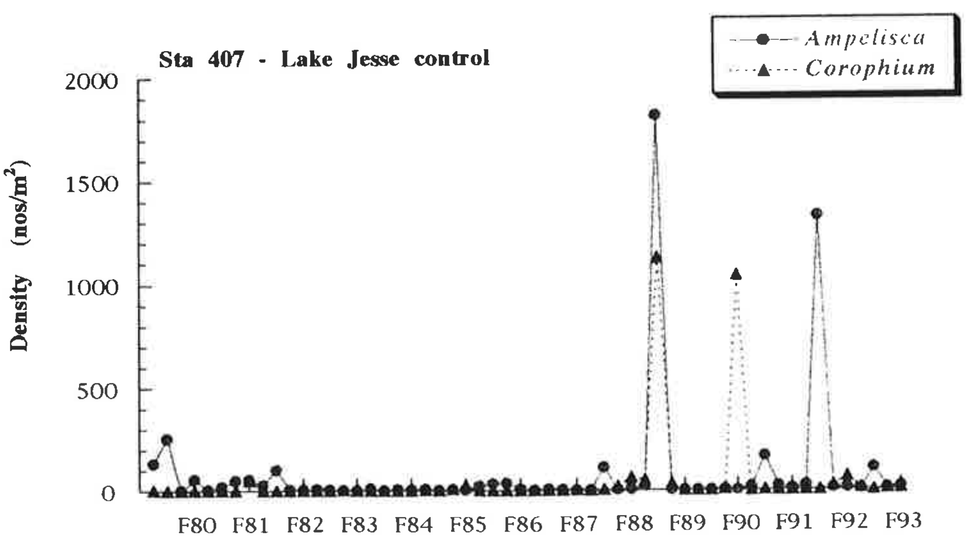
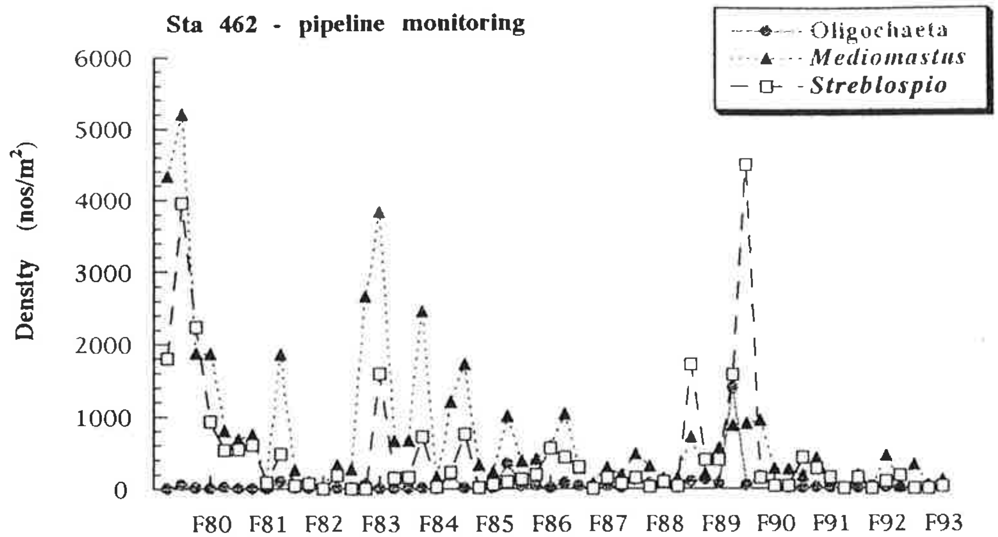
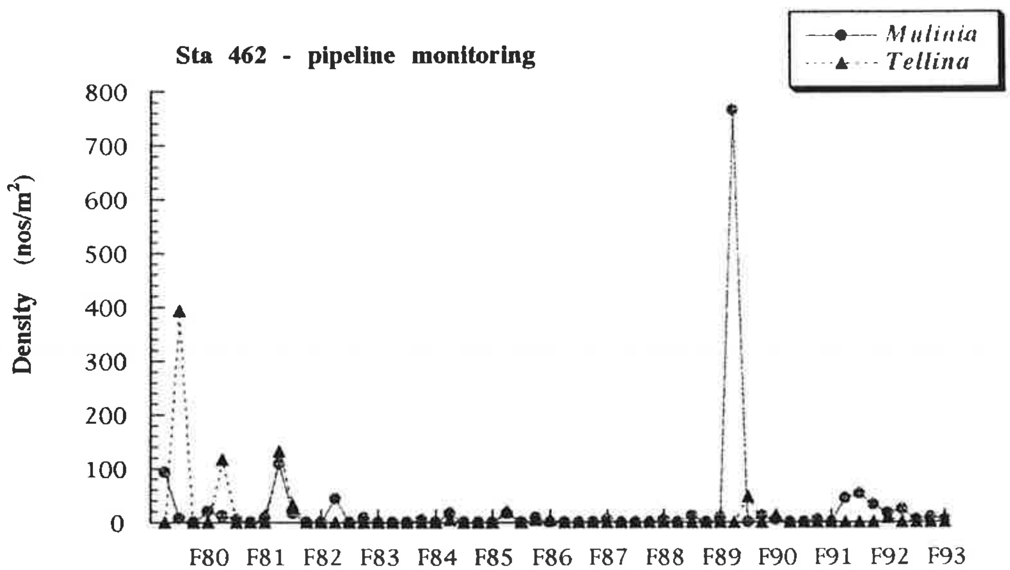


Figure 20. Yearly density summaries of dominant taxa/species for the pipeline control station 407.





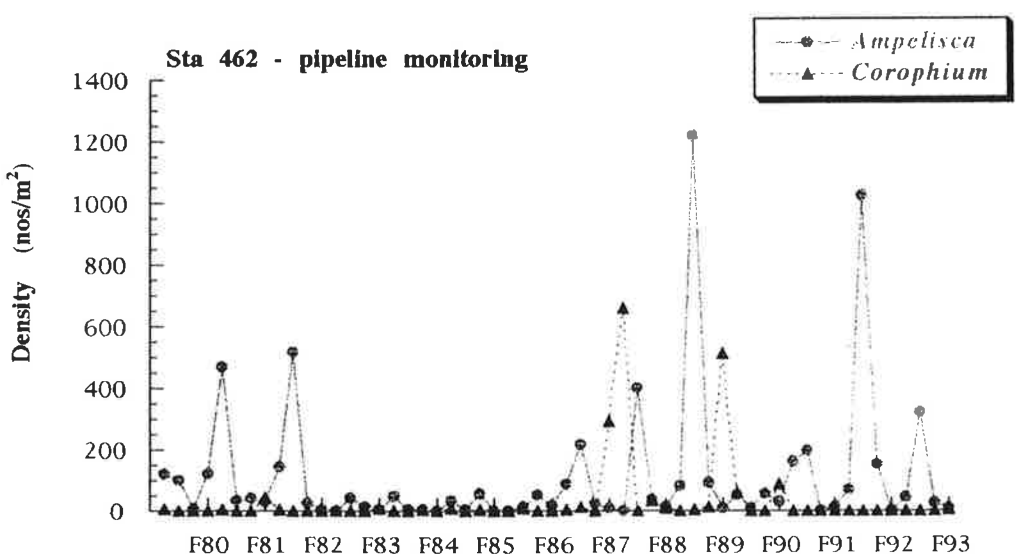
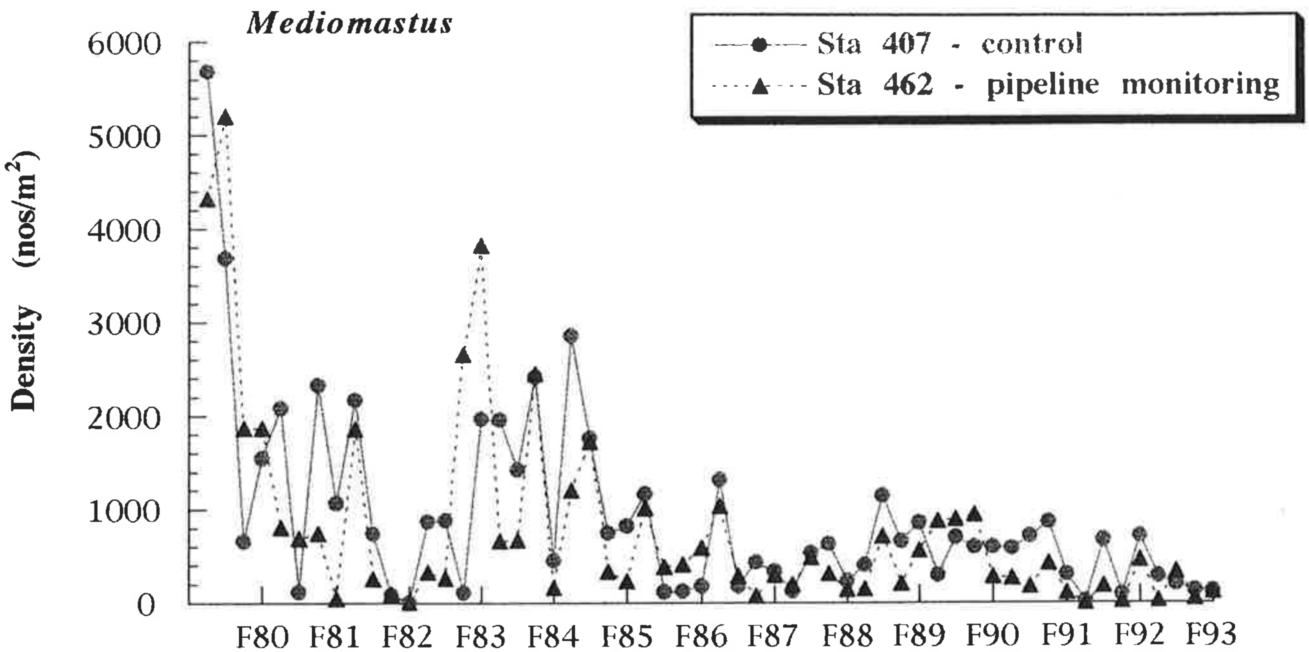


Figure 21. Yearly density summaries of dominant taxa/species for the pipeline monitoring station 462.



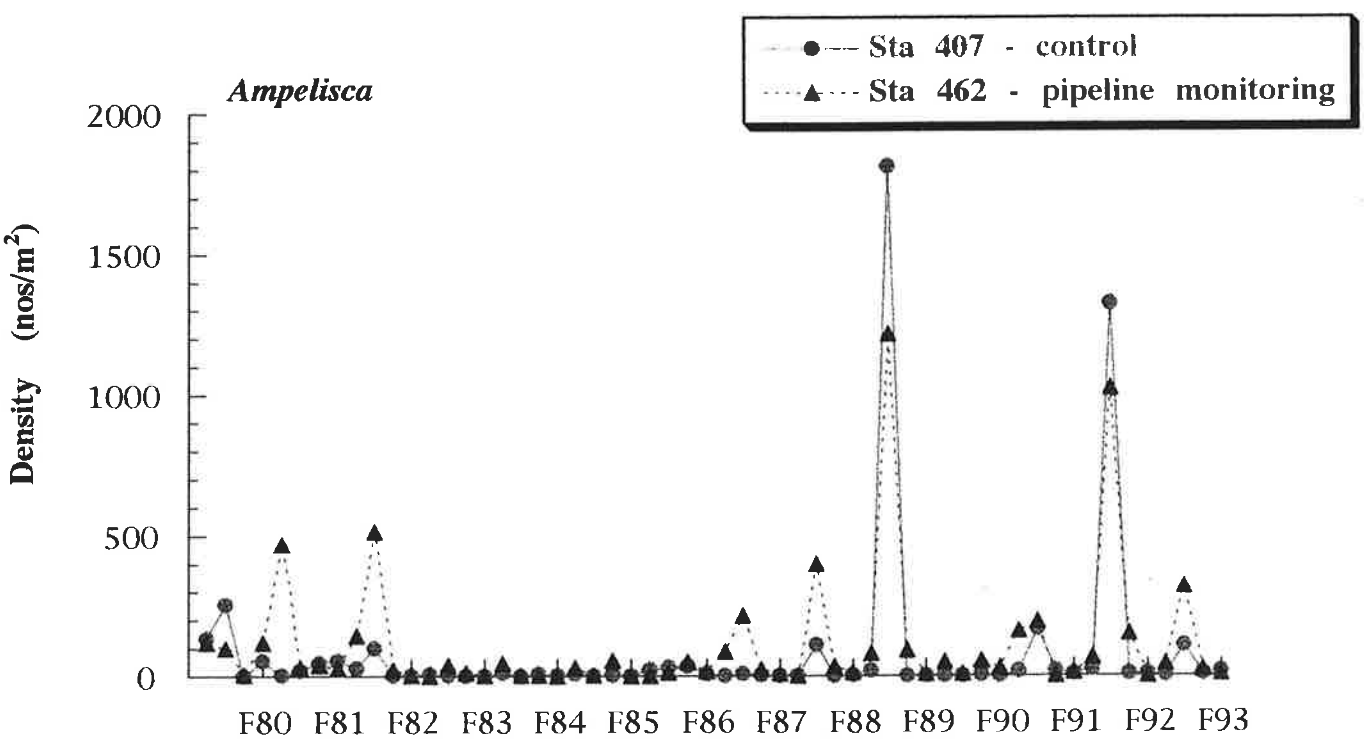


Figure 22. A comparison of yearly densities of the polychaete, *Mediomastus* and the amphipod *Ampelisca* for control station 407 and the pipeline monitoring station 462.

between stations, there were qualitative differences in abundance during a given season (Fig. 22). Both taxa exhibited variable year-to-year recruitment at each station.

RESULTS III. BRINE DIFFUSER

SEASONAL SUMMARY OF HYDROGRAPHY

A seasonal summary of hydrographic characteristics for the brine diffuser control station 435 and monitoring stations 473, 474, and 475 is given in Fig. 23. There was considerable spatial variation in the percentage of sand in the sediments at the three stations. The percentage of sand in the sediment varied from 10% at control station 435 in the winter to 23% at diffuser monitoring station 473 in the spring. The average percent sand was 12.0%, 17.4%, 19.9%, and 12.3% for stations 435, 473, 474, and 475, respectively. Diffuser stations 473 and 474 generally had a higher percentage of sand in the sediments than control station 435 and diffuser station 475 (Fig. 23). There were no spatial or temporal differences in interstitial salinity (Fig. 23). Interstitial salinity averaged 32 ppt for the four stations and ranged from 29 ppt in the spring at control station 435 to 35 ppt at diffuser station 473 during the fall (Fig. 23). There were no differences between stations in bottom dissolved oxygen for a given season. Bottom dissolved oxygen exhibited considerable temporal variability. DO levels observed during the winter and fall sampling periods were twice those measured during the spring and summer (Fig. 23). DO concentrations averaged 6.3, 2.9, 2.6, and 6.2 mg/l for the winter, spring, summer, and fall seasons, respectively. All stations had spring and summer DO levels approaching hypoxia.

SEASONAL SUMMARY OF MACROINFAUNAL ASSEMBLAGE

A seasonal summary of the general characteristics of the macroinfauna assemblage for the brine diffuser control station 435 and monitoring stations 473, 474, and 475 is given in Fig. 24. There were no significant differences between average number of taxa collected and mean total density at the three stations for a given season (Table 6). The mean number of taxa collected was lowest during the summer and averaged 55.6, 55.7, 32.6, and 45.7 for the winter, spring, summer, and fall seasons, respectively (Fig. 24). Densities were highest during the spring months and lowest during the summer months. Densities averaged 4258.0, 6052.7, 2377.8, and 2859.9 individuals/m^2 for the winter, spring, summer, and fall seasons, respectively. There was no between station variation in diversity (H') and diversity averaged 2.3, 2.2, 1.7, and 2.1 for the winter, spring, summer, and fall seasons, respectively (Fig. 24).